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Forest Litter and Humus Types of East Tennessee

John Thurlow McGinnis
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by John Thurlow McGinnis entitled "Forest Litter and Humus Types of East Tennessee." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Botany.

Fred. H. Norris, Major Professor

We have read this thesis and recommend its acceptance:

G. E. Hunt, H. R. DeSelm, L. F. Seatz

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

August, 1958

To the Graduate Council:

I am submitting herewith a thesis written by John Thurlow McGinnis entitled "Forest Litter and Humus Types of East Tennessee." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Botany.

Major Professor

We have read this thesis
and recommend its acceptance:

Lloyd F. Seatz

Accepted for the Council:

Dean of the Graduate School

FOREST LITTER AND HUMUS TYPES OF EAST TENNESSEE

A THESIS

Submitted to
The Graduate Council
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Master of Science

by

John Thurlow McGinnis

August 1958

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I. INTRODUCTION

Forest litter and humus types in east Tennessee, including the Great Smoky Mountains, have been the object of this study. The east Tennessee area is bordered on the east by the State Line Ridge in the Smoky Mountains and on the west by the Cumberland Mountains. The east Tennessee area is in the Ridge and Valley and Blue Ridge provinces as defined by Fenneman (1938). The Great Smoky Mountains, in the Blue Ridge province, are part of the Unaka Chain (King and Stupka 1950) and have relief of over a mile. The Ridge and Valley province is an intermountain belt, consisting of a series of parallel ridges and intervening valleys extending in a northeast-southwest direction and the relief is generally less than 800 feet. Accordingly east Tennessee is characterized by variety in its vegetation, climate and soils. Although forest litter and humus types are of primary interest in understanding the interlocking relationships of vegetation, climate and soils, their details have often been overlooked.

II. LITERATURE SURVEY

According to Waksman (1938) the term "humus" dates back to the time of the Romans when it was used for the soil as a whole. Waksman also states that as early as 1826 Sprengel, and later in 1875 Emeis, noticed that humus types varied and had distinct characteristics under different conditions. Linneaus (1707-1778) classified soils as he did plants by a binomial system. One of the various soil types recognized was Humus daedalea for garden soil. Wallerius (1761, Waksman 1938) first defined humus in terms of decomposed organic matter. The development and terminology of humus layer types are discussed in detail by Romell and Heiberg (1931), Heiberg (1937) and Waksman (1938). These authors illustrate the difficulties encountered tracing the evolution of terminology.

Muller (1887), (quoted by Lutz and Chandler 1946), a Danish scientist, was one of the first to regard humus layers as natural biological units. He recognized two principle kinds of humus layers, mull and mor (words both of Danish origin), and characterized them in terms of their biological and ecological properties.

In later descriptive study it became necessary to distinguish between strata of the humus layer and designations for each were proposed. In 1926 Hesselman (reported by Lutz and Chandler 1946) recognized three strata, or layers, as follows:

1. Litter or L layer, the layer consisting of unaltered dead remains of plants and animals. Strictly speaking litter is not humus or a part of the humus layer. Some workers designate the litter layer as the A_{00} horizon.

2. F layer, the layer consisting of partly decomposed organic matter. The structure of the plant debris is generally well enough preserved to permit identification of its source.

3. H layer, the layer consisting for the most part of well-decomposed, amorphous organic matter. Some workers designate the combined F and H layers of mor types as the A_0 horizon.

These designations are still popular especially with foresters. The F layer and the H layer are now often referred to as the fermentation and the humus layers respectively. These different strata will be referred to as layers throughout this paper and have the same meaning as those prescribed by Hesselman. If the amorphous organic matter is intimately mixed with the top layer of the mineral soil the horizon will be designated by the now popular designation A_1 rather than mull humus layer from older classifications.

Bornebusch and Heiberg (1936) proposed a nomenclature of forest humus layers which was later revised by Heiberg and Chandler (1941). The system now generally used in the United States is a further revision by Hoover and Lunt (1952). This last revision is the one used in classification of forest humus types in this paper. (see appendix).

The differentiation between the three major humus types; mull, duff mull, and mor is based on the degree of incorporation of organic matter into the mineral soil. "Mull humus" is a term used to describe the condition where no H layer accumulates on top of the mineral soil. The organic matter is well mixed with the upper part of the mineral soil. In contrast, "mor humus" is used to describe the condition in which an

H layer does accumulate above the mineral soil with little if any mixing of organic matter with the upper part of the mineral soil. The term "duff mull" is used to describe the condition where there is a combination of mull and mor types with an H accumulation as well as incorporation of organic matter into the mineral soil.

The actual cause and effect relationships in the formation of mull and mor humus types have not been satisfactorily explained. Recently Handly (1954) reported the reasons for the differential formation of mull and mor. He concluded that stabilized leaf proteins are an important factor in the processes of mor formation.

Forest litter is considered as an important part of humus formation. Each year a certain amount of litter is added to the forest floor, which adds to the total accumulation of organic matter above the mineral soil. Under equilibrium conditions this annual addition is proportional to the annual rate of decomposition. Thus a dynamic relationship is maintained. The rate of decomposition, as stressed by Waksman (1938), depends on environmental influences on microorganisms.

In North Carolina, Sims (1932) reported pine-oak total litter accumulations of 3 to 4 tons per acre. Blow (1955) reports a maximum forest floor weight of 5.4 tons per acre in December for an upland oak stand in east Tennessee. In upland oak stands in eastern Tennessee, Perry and Burrage (1939-1945) found litter accumulations at 5 year intervals varied from 6 to 8 tons per acre. Auten (1941) reported accumulations of 7 to 10 tons per acre in oak stands in the central states region.

In a comparison of northern and southern Appalachian virgin spruce-fir forests, Oosting and Billings (1951) reported that the organic horizons were much thinner and there was more difficulty in detecting the L, F, and H layers in the south than in the north. Morgan and Lunt (1931) reported 271,081 pounds per acre of total organic matter for a thin podsol in Union, Connecticut, and 544,450 pounds per acre for a thick podsol in the same area.

III. CLIMATE

The climate of the Valley and Ridge province is temperate and continental. The summers are long and warm and the winters are short and moderate. The mean summer temperatures range from 72 to 77° F. and the mean winter temperatures range from 34 to 42° F. with yearly averages ranging from 54 to 58° F. The difference between mean winter and mean summer temperatures is about 37° F. (figures from Climate and Man, 1941). The highest temperatures and lowest temperatures range between 112° F. and -32° F. The ground is seldom covered with snow more than a few days, and soil freezes to a depth of only a few inches for short periods. In east Tennessee the average growing season ranges from 180 days in the north to 210 days in the south.

The rainfall is evenly distributed through the winter, spring, and summer months with the driest period occuring during the fall. The average annual precipitation ranges from about 40 inches in the north to 55 inches in the south. Local climatic differences in the counties result from local variations in elevation and relief.

The Great Smoky Mountains with a relief of 5,183 feet between Park Headquarters and the top of Clingman's Dome are characterized by great variation in climate. Temperature and precipitation data for a five year period have been studied by Shanks (1954). The data show a range in mean annual temperature from 56.6° F. at 1,460 feet elevation to 45.8° F. at 6,300 feet near the top of Clingman's Dome. The average rate of temperature decrease with altitude is 2.23° F. per thousand feet. The reported mean annual precipitation ranges from 57.8 inches at 1,460 feet to 90.9 inches at 6,300 feet. These data suggest a perhumid climate at higher altitudes (Shanks 1954).

IV. METHODS

Field Observations

Stand Selection and Description

Stands representative of the major forest types present in east Tennessee were selected for collecting sites. At each site notes were taken on major contributors to litter and on the relative abundance, size and general dominance of the plants in the sample area.

At each stand, county, site location, elevation, per cent slope, and exposure were recorded. The species present were listed, using nomenclature as included in *Gray's Manual of Botany* (Fernald, 1950).

The sampling in the stands was done in late winter and early spring of 1958. The stands in which investigations were carried out are described below. Locations and sample descriptions are included under Results and Discussion.

1. Spruce-Fir. Most of the stand studied was an undisturbed forest with a closed canopy. The two dominant species of trees were *Picea rubens* and *Abies Fraseri*. A very sparse shrub society of *Viburnum alnifolium* was present under the canopy. The forest floor was covered, almost entirely in some places, with *Oxalis montana* together with dense mats of *Hylocomium splendens*. Where the forest floor was not "living" the litter consisted of mixed needles of spruce and fir. Also present on the forest floor were many rotting tree trunks of spruce and fir. Many of these trunks were covered with mosses and lichens. Thus the forest floor is very uneven with numerous holes due to uprooting. Near

the edge of the spruce-fir forest, adjoining a beech gap, many leaves of beech and birch were scattered in the litter.

2. Beech gap. This area with a concave slope joined the Spruce-Fir (No. 1) which had a convex surface. The stand was undisturbed with a moderately well closed canopy, the major trees being Fagus grandifolia and some Betula allegheniensis. The vegetation on the forest floor consisted mostly of sedges, ferns, and herbs. The litter was generally stable on the steep slope with occasional losses only due to surface runoff.

3. Table Mt. Pine. This stand was on a steep ridge with southern exposure. The forest had not been cut and had not been burned for thirty years (personal communication from Randolph Shields 1958). The canopy was closed and consisted of two major species, mainly Pinus pungens and P. virginiana. Locally large trees of Quercus Prinus were present but these contributed only a minor part to the total litter. Present in the shrub society were scattered Ericaceous plants. The litter was composed mostly of pine needles with occasional tree trunks. Ground cover was sparse with only a few patches of mosses and lichens present.

4. Oak-pine. This was a closed-canopy secondary stand of oak and pine of about three acres extent which apparently had not been disturbed for several years. Two pine trees, 15" diameter breast height, had recently been cut and were approximately sixty-five years old. Approximately two-thirds of the canopy trees were Pinus echinata with the rest of the canopy being a mixture of Quercus velutina and Q. falcata. In the understory were some small trees of Fagus grandifolia and Cornus

florida. Most of the forest floor at the edge of the stand was covered with Lonicera japonica to such an extent that walking was difficult. The litter was a mixture of pine needles and deciduous leaves, the deciduous leaves masking, for the most part, the presence of the pine needles.

5. Scrub pine. This rather dense stand of small-diameter pine was still in the early stages of succession. Farming on the site had ceased approximately fifteen years ago and the site has been undisturbed since. The major species comprising the canopy was Pinus virginiana. The understory was composed of Cornus florida, Liquidamber styraciflua, Quercus velutina, Acer rubrum, Juniperus virginiana and Ulmus alata. Shrubs and vines were principally Euonymus americanus, Smilax sp. and Bignonia capreolata. Many mosses, lichens, and fruiting fungi were observed from time to time on the forest floor. Many small dead tree trunks of pine were scattered about due to natural thinning.

6. Red cedar. This was a very small stand (approximately ½ acre) that had not been recently cleared and farmed. The canopy was not tightly closed and the ages of the trees were estimated to be over thirty years. No recent clearing of trees was observed. The sole species comprising the canopy was Juniperus virginiana. The understory consisted of Cercis canadensis about eight feet tall, almost one-fourth the height of the red cedar canopy. Other minor litter contributors were Lonicera japonica and Rubus sp. Apparently several herbs were present through the growing season as evidenced by dead stems remaining on the forest floor. Even considering the redbud and herb contribution, the litter

layer was very thin and consisted mainly of red cedar needles.

7. Hemlock-hardwood. This stand had a closed canopy and had not been disturbed. The stand is a narrow band ranging from 100 to 200 feet wide, on each side of a small creek. In the area sampled, there were several trees of *Tsuga canadensis* over 2 feet in diameter and one of *Fagus grandifolia* over 2 feet in diameter. Other contributing species were *Magnolia Fraseri*, *Liriodendron tulipifera*, *Betula allegheniensis* and a large *Sassafras albidum*. *Quercus velutina* leaves were observed in the litter and apparently had blown into the site from the adjacent hillside. There was a very dense growth of *Rhododendron maximum* which contributed a major amount of leaves and twigs to the litter. The forest floor was also cluttered with many hemlock logs that were covered with mosses.

8. Mixed hardwood. This stand was on a moderately steep slope above the hemlock-hardwood stand. There apparently had been no disturbance by fire or cutting in recent times. The major contributors to the litter were *Acer rubrum*, *Halesia carolina*, *Liriodendron tulipifera*, *Fagus grandifolia*, *Carya sp.*, and *Quercus velutina* which was mostly higher on the slope. *Tsuga canadensis* seedlings were very common on the lower part of the slope but higher on the slope than the *Rhododendron*. Occasional dead (standing and fallen) trunks of *Castanea dentata* were present. Several tree trunks had been upturned, exposing shallow root systems. The trees fell rather consistently in the down-slope direction.

9. Mixed mesophytic. This stand was very similar to the mixed hardwood stand but was composed of more mesic species. The canopy was well mixed, with the major contributing species being: *Acer saccharum*,

Aesculus octandra, Tilia heterophylla, Halesia carolina, Liriodendron tulipifera, Tsuga canadensis and Carya sp. The area was park-like in appearance with numerous upturned tree trunks scattered about.

10. Chestnut oak. This stand was located near the top of a ridge with a moderately steep slope and showed evidence of selective cutting, over 15 years ago. It was a mature stand with a closed canopy comprised mostly of Quercus Prinus and with Q. velutina, Acer rubrum and Carya sp. also contributing to the litter. Fallen trees were not common but many large stumps of Castanea dentata were present.

11. Mixed oak. This was a closed-canopy forest which had had selective cutting through the years. The major canopy contributing species were: Quercus alba and Q. velutina with a mixture of Q. rubra, Liriodendron tulipifera and Carya sp., Cornus florida, Acer rubrum, Castanea pumila, Fagus grandifolia and an occasional Sassafras albidum were present in the understory. Not many fallen trees were evident because of cutting of overmature trees.

12. Mixed oak-hardwood. This was a mature forest stand, on virgin soil, with a selective-cutting history. The stand was cleared almost immediately after sampling. The canopy species contributing litter were: Quercus alba, Q. velutina, Q. falcata, Q. coccinea, Carya ovalis, Liriodendron tulipifera, Acer rubrum and Pinus echinata. In the understory, the species found were: Cornus florida, Sassafras albidum, Diospyros virginiana, Oxydendron arboreum, Nyssa sylvatica, Ulmus americana and Juniperus virginiana. Several Castanea dentata stumps with sprouts were present but as a very minor contributor to the litter. In the trans-

gressive group Cercis canadensis and Amalanchier arboreum were found. Seedlings of all of the above, except chestnut, were found. Many shrubs, vines and herbs were present on the forest floor during the growing season, including Rhus radicans, Lonicera japonica, Vaccinium stamineum, Euonymus americanus, Parthenocissus quinquefolia and Vitis sp.

13. Oak-hickory. This stand was between the scrub pine (No. 5) at the base of a slope and chestnut oak (No. 10) at the top of the slope. It is a cut-over stand (over 15 years ago) in which Quercus alba, Q. velutina, Q. Prinus, Q. rubra, Carya sp., Acer rubrum, and Liriodendron tulipifera contribute the major amount of litter. In the understory, Cornus florida, Fagus grandifolia, Faxinus americana, Cercis canadensis, Sassafras albidum, Oxydendrum arboreum, and Juniperus virginiana contribute to a lesser extent. Some local spots are denuded of litter by heavy wind and runoff.

14. White oak. This was an undisturbed closed canopy site with apparently virgin timber and soil. The major canopy species was Quercus alba, with a lesser combination of Quercus velutina, Q. Prinus, Fagus grandifolia, and Acer rubrum. In the understory, Ulmus americana, Magnolia acuminata, Cornus florida, Cercis canadensis and an occasional Juniperus virginiana were found. Litter on the forest floor was often thin or absent on limestone outcrops and in places where runoff caused relocation of the litter. Several fallen trees were present on the forest floor.

Litter Yield Collections

Twenty - 1/10 milacre boxes, 2.08 feet square, on legs, similar to those described by Blow (1955), and with No. 12 window screen wire bottoms were constructed and placed in the field. Two rows of boxes, numbers 1-9 were placed in order up a north facing slope, the rest of the boxes, numbers 10-20, were placed on a northeast facing slope on Copper Ridge. The stands in which these were located, were the scrub pine (box numbers 1-4 and 20) and oak-hickory (box numbers 5-19). The boxes were set out in mid August, 1957, and collections made every month or oftener. The collections ended for this study on June 16, 1958. Total dry weights were taken for each sample in grams, averages computed and these converted to pounds per acre for the two stands. It is believed that the averages obtained from random placement of the collecting boxes provide a basis for good estimates of the yield for the two stands. On a few of the collections separation of the leaves from twigs, bark and fruits were made and a percentage of materials other than leaves was calculated.

Forest Floor and Soil

In 13 of the 14 kinds of stands described earlier five or more samples of the forest floor and mineral soil were collected. In the chestnut oak stand only two samples were taken. Sample sites were selected randomly within stands but usually samples were taken not closer than six feet from the trunks of large trees. Under the oak-hickory and scrub pine stands, samples were taken beside each of the 1/10 milacre litter boxes.

In collecting a sample, a one decimeter square aluminum plate first was placed on top of the litter and with a knife a deep cut was made around the edges of the plate taking care not to disturb the materials under the plate. The surrounding litter was then raked away. Next, with a heavy knife and a trenching shovel a vertical column was exposed. The column was then inspected and layers and horizons determined and measurements on each were tabulated. Observations were made on texture, structure, and color of the H layer if present and on each horizon. The texture was estimated by rubbing the materials between the thumb and index finger. The color rating was obtained by comparison with a color chart. (Munsell Soil Color Charts, 1954 ed.). All materials were collected including roots and rocks. If a very large root or rock was present in the column, a new column was exposed a few inches away. With a sharp knife each layer or horizon was separated, again measured and placed in a labeled sack and brought into the laboratory. The lowest sample taken at each place in each stand does not necessarily represent the total composite character of the B horizon but in most cases only that of the upper portion, usually less than 10 centimeters deep. This was especially true if the soil was deep over the bedrock.

Laboratory Analysis

Forest Floor and Soil

The samples were placed, as soon as possible after collection, in a forced draft oven at 105° Centigrade for 24 hours, and therefore all laboratory analyses of the materials collected were on oven dried material. After drying, each sample was weighed and bulk densities were calculated.

Collecting sites were located on topographic maps and those maps available in county soil survey bulletins (surveys of Sevier 1956, Knox 1955, Sullivan 1953 Counties and Norris Area 1953, Tennessee), and correlations of field data and soil survey descriptions were made. Soil types were then assigned to the soil at each site. For the high mountain soils, soil survey descriptions and soil type names are incomplete. The soil descriptions presented here from such areas are strictly from field notes.

Out of the five profile samples for each stand, two were selected as modal individuals and on these carbon, nitrogen, calcium and potassium determinations were made. The pH was determined for all H layers and mineral horizons of all samples.

Preparations of samples for determination of exchangeable calcium and potassium were modifications of the method described by Shaw and Veal (1956). Samples for total calcium and potassium determination were prepared by a method similar to that described by Gieseking, Snider, and Getz (1935). Determinations were made on Beckman flame spectrophotometer. Total nitrogen was determined by the Kjeldahl method as described by Jackson (1958).

Total carbon and organic matter were determined by a combination of the Walkley-Black and Schollenberger Method with modifications as described by Jackson (1958). The results of this method were compared with checks run by the loss on ignition method by heating samples to 525° C. for 45 minutes and by the method in Assoc. Off. Agr. Chem. (1955).

Correlations were made with recovery factors, and carbon ratio to organic matter factors were calculated. The analytical procedures about the analyses used are given in the appendix.

V. RESULTS AND DISCUSSION

Descriptions of the Forest Floor and Soils

The following profile descriptions are based on both field data and laboratory study. The mineral strata were designated by standard horizon symbols. The break between the bottom of the organic layers or forest floor and the mineral soil was used in these descriptions as the zero point for measurement of depth. The positive figures represent contiguous thicknesses downward from the zero point and the minus figures represent contiguous thicknesses upward from the zero point. Metric linear measure in centimeters was used in measurement of the thicknesses of layers and horizons for convenience.

SPRUCE-FIR

Location: Southeast-facing slope with a gradient of 40-50 per cent, 0.8 miles from Newfound Gap on the north side of Clingman's Dome road, Great Smoky Mountains National Park.

Elevation: 5200 feet.

Parent Material: Graywacke.

Soil Type: Rough mountainous land (Ramsey soil material), acid brown soil.

Profile:

L (-5.6 to -5.0 cm.) Matted, green, bound together with mosses; needles intermingled with moss; bulk density 0.118 g./cc.

F	(-5.0 to -4.0 cm.)	Also matted; consists of moss rhizoids and undecomposed needles; bulk density 0.164 g./cc.
H-1	(-4.0 to -1.0 cm.)	Black (10YR 2/1), felty; may be gray due to fungal hyphae in spring; bulk density 0.212 g./cc.
H-2	(-1.0 to 0.0 cm.)	Black (10YR 2/1), greasy, granular; with many roots in H-1 and H-2; bulk density 0.288 g./cc.
A_1	(0.0 to 5.1 cm.)	Dark brown (10YR 3/3) very fine sandy loan, friable; 12.8 per cent materials larger than 2 mm. May or may not be underlain with incipient A_2; bulk density 0.820 g./cc.
AB	(5.1 to 8.5 cm.)	Dark yellowish brown (10YR 4/4) silt loam; not a horizon but an overlap of transition from A to B that is wavy; roots scarce; 11 per cent materials larger than 2 mm.; bulk density 1.142 g./cc.
B	(8.5 to 13.9 cm.) collected	Yellowish brown (10YR 5/6-5/8) light clay loam; angular blocky structure; 8.9 per cent materials larger than 2 mm.; bulk density 1.264 g./cc.

BEECH GAP

Location: South-facing slope with a gradient of 35 to 45 per cent, on north side of road 0.8 miles from Newfound Gap on the Clingman's Dome road, Great Smoky Mountains National Park.

Elevation: 5200 feet.

Parent Material: Local colluvium from Graywacke.

Soil Type: Rough mountainous land (Ramsey soil material).

Profile:

L	(-2.6 to -0.6 cm.)	Leaves loose, fluffy, easily stirred and disturbed by growth of early spring herbs; bulk density 0.014 g./cc.
F	(-0.6 to 0.0 cm.)	Thin gradational to A_1; bulk density 0.105 g./cc.
A_1	(0.0 to 5.0 cm.)	Dark brown (7.5YR 3/2) friable, granular silt loam; bulk density 0.873 g./cc. with 31.8 per cent materials larger than 2 mm., intergrading with AB layer.
AB	(5.0 to 10.1 cm.)	Dark yellowish brown (10YR 4/4) silty clay loam; bulk density 1.179 g./cc. with 19.6 per cent materials larger than 2 mm., intergrading into B_1.
B_1	(10.1 to 17.1 cm.)	Brown (7.5YR 4/4) clay loam; bulk density 1.165 g./cc. with 18.1 per cent materials larger than 2 mm.

TABLE MT. PINE

Location: South-facing slope with a gradient of 40-55 per cent, about 1.0 mile up Cobb Ridge on the south side of Cades Cove, Great Smoky Mountains National Park.

Elevation: 2800 feet.

Parent Material: Shale.

Soil Type: Rough mountainous land (Ramsey soil material).

Profile:

L	(-2.8 to -1.7 cm.)	Litter mostly of table mt. pine and scrub pine needles; bulk density 0.074 g./cc.
F	(-1.7 to -1.2 cm.)	Light blue gray due to abundance of fungal hyphae; bulk density 0.092 g./cc., intergrading into H layer.
H	(-1.2 to 0.0 cm.)	Also light gray due to fungal hyphae, very loose; bulk density 0.207 g./cc., intergrading into A_1.
A_1	(0.0 to 2.0 cm.)	Very dark brown (10YR 2/2), friable silt loam; bulk density 0.728 g./cc. with 46.9 per cent materials larger than 2 mm.
AB	(2.0 to 5.0 cm.)	Dark yellowish brown (10YR 4/4), friable silty clay loam; bulk density 0.954 g./cc. with 48.2 per cent materials larger than 2 mm.

B ? (5.0 to 9.7 cm.) collected — Yellowish brown (10YR 5/6), plastic silty clay, very shallow to bedrock; bulk density 1.044 g./cc. with 44.4 per cent larger than 2 mm.

OAK-PINE

Location: South-facing slope with a gradient of 4 per cent, 0.6 of a mile northwest of Knoxville city limits on highway 62, the south side of the road, Knox Co.

Elevation: 1000 feet.

Parent Material: Cherty limestone.

Soil Type: Greendale silt loam.

Profile:

L	(-3.3 to -1.0 cm.)	Litter of pine needles and oak leaves well mixed; bulk density 0.042 g./cc.
F	(-1.0 to 0.0 cm.)	Both pine and oak litter rather well decomposed and with rapid incorporation into next horizon; bulk density 0.104 g./cc.
A_1	(0.0 to 6.0 cm.)	Very dark gray brown (10YR 3/2), silt loam, with good root distribution; bulk density 1.075 g./cc. with 24.9 per cent materials larger than 2 mm.
B	(6.0 to 11.3 cm.) collected	Dark yellowish brown (10YR 4/4), firm but friable silty clay loam; bulk

density 1.305 g./cc. with 20 per cent materials larger than 2 mm.

SCRUB PINE

Location: North-facing slope with a 6-10 per cent gradient at the foot of Copper Ridge adjacent to White Oak Lake Bed, about 0.3 of a mile up from dam at highway, Roane Co.

Elevation: 800 feet.

Parent Material: Shale interbedded with limestone.

Soil Type: Armuchee silt loam.

Profile:

L	(-2.8 to -1.3 cm.)	Litter mostly pine needles mixed with some dogwood leaves, surface partially covered with lichens; bulk density 0.080 g./cc.
F&H	(-1.3 to 0.0 cm.)	Black, felty due to abundance of fungal hyphae; neither horizon thick nor distinct enough to separate; bulk density 0.173 g./cc.; changining rather abruptly to:
A	(0.0 to 1.8 cm.)	Gray brown (10YR 5/2), silt loam, with weak crumb structure; shallow; bulk density 0.919 g./cc. with 17.1 per cent materials larger than 2 mm.; mostly small fragments of shale.

B (1.8 to 3.9 cm.) collected — Yellowish brown (10YR 5/4), silt loam to silty clay loam; bulk density 1.296 g./cc. with 14.9 per cent materials larger than 2 mm.; shallow to bedrock; area has not been farmed for about fifteen years.

RED CEDAR

Location: South-facing slope with approximately 6 per cent gradient, 4.3 miles west of U.T.-A.E.C. Farm Experiment Station on the south side of highway 62; about 1 acre in extent and probably an old home-site at least 30 years ago. Anderson Co.

Elevation: 850 feet.

Parent Material: Limestone.

Soil Type: Colbert silty clay loam.

Profile:

L	(-0.6 to -0.3 cm.)	Litter mostly from cedar with scattered leaves of redbud, a moderately smooth surface; bulk density 0.053 g./cc.
F	(-0.3 to 0.0 cm.)	Dark, thin, predominated by decomposing cedar needles that are rapidly becoming incorporated into the next horizon; bulk density 0.123 g./cc.
A_1	(0.0 to 4.1 cm.)	Very dark brown (10YR 2/2), fairly friable silty clay loam; roots well

distributed; bulk density 0.753 g./cc. with 11.8 per cent materials larger than 2 mm.

C (4.1 to 9.8 cm.) collected — Dark brown (10YR 3/3), plastic silty clay; shallow to bedrock; bulk density 1.167 g./cc. with 34.3 per cent materials larger than 2 mm.

HEMLOCK-HARDWOOD

Location: Bottom land on north-facing slope with a 5-7 per cent gradient, ¼ mile down-trail from "the big poplar" on the trail to Gregory's Bald, south side of Cades Cove, Great Smoky Mountains National Park.

Elevation: 2100 feet.

Parent Material: Sandstone.

Soil Type: In the Ramsey series.

Profile:

L (-3.7 to -1.7 cm.) — Forest floor covered with many dead twigs and rolled leaves from *Rhododendron* understory and with hemlock needles intermixed. Many hardwood leaves present from canopy on adjacent steep slope; bulk density 0.028 g./cc.

F (-1.7 to 0.0 cm.) — Variable due to twigs and number of *Rhododendron* leaves; bulk density 0.105 g./cc., intergrading into A_1.

A_1	(0.0 to 6.2 cm.)	Black (10YR 2/1) silt loam, granular structure; roots mostly in this horizon and in the F horizon; bulk density 0.501 g./cc. with 8.1 per cent larger than 2 mm., intergrading into B horizon.
B	(6.2 to 12.2 cm.) collected	Dark brown (10YR 4/3) silty clay loam; bulk density 0.806 g./cc. with 6.4 per cent materials larger than 2 mm.

MIXED HARDWOOD

Location: North-facing slope with 20 per cent gradient, adjacent to Hemlock-hardwood bottom about $\frac{1}{4}$ mile down-trail from "the big poplar" on the trail to Gregory's Bald on the south side of Cades Cove, Great Smoky Mountains National Park.

Elevation: 2100 feet.

Parent Material: Sandstone.

Soil Type: In the Ramsey series.

Profile:

L	(-2.4 to -0.8 cm.)	Leaves forming a continuous mat but loose enough to be easily stirred. Many leaves show signs of retting by early March; bulk density 0.036 g./cc.
F	(-0.8 to 0.0 cm.)	Only leaf petioles, leaf veins, and remnants of twigs remaining with apparently rapid incorporation of

organic matter into the horizon below, boundary very gradational; bulk density 0.074 g./cc.

A_1 (0.0 to 8.4 cm.) Black (10YR 2/1) silt loam, friable with medium granular structure; horizons indistinct with organic matter decreasing with depth; bulk density 0.632 g./cc. with 16.9 per cent materials larger than 2 mm.

B (8.4 to 16.0 cm.) collected Very dark brown (10YR 2/2) silty clay loam; fewer roots than in A horizon; bulk density 0.849 g./cc. with 17.8 per cent materials larger than 2 mm.

MIXED MESOPHYTIC

Location: North-east facing slope with a gradient of 45-60 per cent, about 1.0 mile up Ekaneetlee Creek on the south side of Cades Cove.

Elevation: 2700 feet.

Parent Material: Sandstone.

Soil Type: Ramsey series.

Profile:

L (-1.9 to -0.8 cm.) Leaves forming a continuous mat but loose enough to be easily stirred, many leaves show signs of retting by early March; bulk density 0.048 g./cc.

F	(-0.8 to 0.0 cm.)	Leaves rapidly decomposed and organic matter incorporated into horizon below; bulk density 0.094 g./cc.
A	(0.0 to 4.2 cm.)	Very dark brown (10YR 2/2) silt loam with medium granular structure; most of the roots present in this horizon; bulk density 0.712 g./cc. with 18.8 per cent materials larger than 2 mm.; organic matter decreasing with depth; intergrading into B horizon.
B	(4.2 to 0.1 cm.) collected	Dark brown (10YR 4/3) silty clay loam; bulk density of 1.115 g./cc. with 22.4 per cent materials larger than 2 mm.; in some places the B horizon was over 1 meter in depth and contained very few roots.

CHESTNUT OAK

Location: North-facing slope with a gradient of 8-10 per cent on Copper Ridge above White Oak Lake Bed, 0.3 miles above the dam, Roane Co.

Elevation: 1000 feet.

Parent Material: High-grade limestone.

Soil Type: Dewey silt loam.

Profile:

L	(-3.5 to -1.5 cm.)	Leaves firm, chiefly of chestnut oak; bulk density 0.038 g./cc.
F	(-1.5 to 0.0 cm.)	Decomposition moderately rapid, bulk density 0.134 g./cc.
A_1	(0.0 to 3.5 cm.)	Very dark gray brown (10YR 3/2) silt loam, with good crumb structure, and with very good incorporation of organic matter; roots well distributed in both A and B horizons, horizons transitional; bulk density 0.659 g./cc. with 11.4 per cent materials larger than 2 mm.; intergrading into B.
B	(3.5 to 8.0 cm.)	Dark reddish brown (5YR 3/4) firm but friable silty clay with soft subangular aggregates; bulk density 0.826 g./cc. with 13 per cent larger than 2 mm.

MIXED OAK

Location: North-facing slope with a gradient up to 15 per cent; 1.7 miles north, 1.6 miles west, and 0.3 miles south of Piney Flats Crossroads, forest on West side of the road near New Bethel Church, Sullivan Co.

Elevation: 1600 feet.

Parent Material: Cherty limestone or Dolomitic limestone.

Soil Type: Dunmore silt loam.

Profile:

L	(-3.3 to -1.1 cm.)	Leaves loose and easily stirred, apparently moderately resistant to late fall and early spring decomposition; bulk density 0.039 g./cc.
F	(-1.1 to 0.0 cm.)	Leaves slowly retted but rapidly incorporated into horizon below; bulk density 0.099 g./cc.
A_1	(0.0 to 4.8 cm.)	Brown (10YR 5/3), silt loam, medium granular structure with roots diffuse through horizons, organic matter diminishing with depth; bulk density 0.850 g./cc. with 11.6 per cent materials larger than 2 mm.
B	(4.8 to 9.7 cm.)	Yellowish brown (10YR 5/4), moderately plastic silty clay loam; bulk density 1.232 g./cc. with 9.7 per cent materials larger than 2 mm.

MIXED OAK-HARDWOOD

Location: South-facing slope with a gradient of 5-12 per cent, 2.6 miles north-west of Knoxville city limits on Tennessee highway 62, Knox Co. Forest on north side of the road.

Elevation: 1000 feet.

Parent Material: Cherty limestone.

Soil Type: Fullerton silt loam.

Profile:

L	(-2.0 to -1.0 cm.)	Leaves coarse, loose, consisting mostly of oak and hickory; bulk density 0.022 g./cc.
F&H	(-1.0 to 0.0 cm.)	Moderate decomposition, granular, appearing as a very weak H horizon in lower part; bulk density 0.103 g./cc.
A_1	(0.0 to 1.1 cm.)	Very dark gray brown (10YR 3/2), friable silt loam, weak granular structure; organic matter in crumbs in upper part of horizon with weak incorporation; bulk density 0.882 g./cc. with 12.7 per cent materials larger than 2 mm.
A_2	(1.1 to 6.1 cm.)	Dark gray brown (10YR 4/2), friable silty clay loam with organic matter rapidly diminishing with depth; roots well scattered in horizon, and horizon boundaries indistinct; bulk density 1.188 g./cc. with 27.9 per cent materials larger than 2 mm.
AB	(6.1 to 9.6 cm.)	Brown to dark brown (7.5YR 4/4), firm silty clay loam; and overlap of transition between A and B horizon; roots common; bulk density 1.338 g./cc. with 15.6 per cent materials larger than 2 mm.

B (9.6 to 14.2 cm.) Reddish yellow (4YR 4/6) firm silty clay; roots also present in this horizon; bulk density 1.345 g./cc. with 9.6 per cent larger than 2 mm.

OAK-HICKORY

Location: North-facing slope with a gradient of 8-20 per cent, slope on south side of the White Oak Lake Bed about 0.3 miles from dam at highway, Roane Co.

Elevation: 900 feet.

Parent Material: Cherty dolomitic limestone.

Soil Type: Fullerton cherty silt loam.

Profile:

L (-3.6 to -1.0 cm.) Leaves loose, mostly species of oak and hickory; bulk density 0.039 g./cc.

F (-1.0 to 0.0 cm.) Plant materials moderately rapidly decomposed with organic matter forming granules in lower part of horizon; bulk density 0.111 g./cc.

A (0.0 to 2.5 cm.) Dark brownish gray (10YR 4/2), loose, silt loam stained with organic matter in upper part, horizons shallow but moderately distinct; bulk density 0.937 g./cc. with 13.3 per cent materials larger than 2 mm.

B	(2.5 to 5.5 cm.) collected	Reddish yellow (7.5YR 6/6), only moderately friable silty clay loam; bulk density 1.351 g./cc. with 19.2 per cent materials larger than 2 mm.

WHITE OAK

Location: North-facing slope with a gradient of 35 to 45 per cent, 2 miles southeast of Norris Dam and 0.5 miles east of Eighteenth Century Mill on south side of stream above ford, Anderson Co.

Elevation: 1200 feet.

Parent Material: Cherty dolomite.

Soil Type: Clarksville cherty silt loam.

Profile:

L	(-3.0 to -0.5 cm.)	Litter mostly white oak leaves, easily stirred, appearing fairly resistant to decomposition; bulk density 0.024 g./cc.
F&H	(-0.5 to 0.0 cm.)	Moderate decomposition, crumb type aggregates of organic matter present in lower part of horizon appearing as a very weak H horizon; bulk density 0.110 g./cc.
A_1	(0.0 to 1.1 cm.)	Gray brown (10YR 5/2), loose, floury, cherty silt loam; roots well distributed, organic matter as granules in upper part of horizon; bulk density 1.064 g./cc.

		with 43.2 per cent materials larger than 2 mm.
A_2	(1.1 to 5.5 cm.)	Brown (10YR 5/3), loose, floury silt loam, horizon boundaries rather indistinct; bulk density 1.169 g./cc. with 35.4 per cent materials larger than 2 mm.
AB	(5.5 to 9.5 cm.)	Light brown (7.5YR 6/4), moderately friable cherty silty clay loam; an overlap of transition between A and B horizons; bulk density 1.463 g./cc. with 22.8 per cent materials larger than 2 mm.
B	(9.5 to 14.5 cm.)	Brownish yellow (10YR 6/6), moderately friable silty clay loam, soil often shallow with bedrock outcropping; bulk density 1.411 g./cc. with 22.2 per cent materials larger than 2 mm.

Litter Yield

The average weights of the litter collected in the 1/10 milacre boxes show a litter fall for the period from mid-August 1957 to June 16, 1958 to be 4,450 pounds per acre for the oak-hickory stand and 4,[illegible]00 pounds per acre for the scrub pine stand. All biological remains were collected including large stems which were broken at the edges of the boxes. This was done with the thought that all remains contribute, at least in part, to the forest floor. The figures are about 1,000 pounds per acre higher than those reported by Blow (1955), who removed the large twigs. The figures agree well with Metz (1952) who reported a range of 4,231 to 4,509 pounds per acre for hardwoods and a range of 4,059 to 5,619 pounds per acre for three pine stands. Under the oak-hickory stand, 21 per cent of the litter was twigs, bark, and fruit and under the scrub pine 14.9 per cent twigs, bark, and fruit were collected. The percentage for oak-hickory is some higher than the 15 per cent reported by Metz (1952) for hardwood stands in South Carolina.

Organic matter of the L, F, and H layers in pounds per acre (Table I) are 7,400 for the oak-hickory stand and 10,000 pounds for the scrub pine stand indicating, at least in these instances, that undecomposed litter was about double the annual litter fall.

Forest Floor

Results of per cent total organic matter (Tables IV, V and VI) for the L, F, and H layers were multiplied by the weight bulk density of each layer and converted into pounds of organic matter per acre for the forest stands sampled and are presented in Table I.

The forest stand with the greatest accumulation of organic matter on the forest floor was the spruce-fir stand with approximately eight times the deciduous forests in general, and almost four times the two coniferous stands: table mountain pine and scrub pine. The accumulation was also more than the 66,941 pounds reported for a thin podsol in Union, Connecticut, by Morgan and Lunt (1931), but quite a bit less than 156,928 pounds per acre reported by them for a thick podsol. The layer with the greatest accumulation is the H or humus layer of the spruce-fir stand which has almost 3.8 times more organic matter than the total of the L and F layers.

TABLE I

WEIGHT OF THE UNINCORPORATED ORGANIC MATTER
UNDER EAST TENNESSEE FOREST STANDS
(Pounds of organic matter per acre)

Layer	Spruce-Fir	Beech Gap	Table Mt. Pine	Oak-Pine
L	4,600	2,100	6,800	7,800
F	13,600	3,900	3,800	6,300
H	69,200	0	15,600	0
Total	87,400	6,000	26,200	14,100
Layer	**Scrub Pine**	**Red Cedar**	**Hemlock-Hardwood**	**Mixed Hardwood**
L	10,000	1,400	3,900	4,800
F	10,100[a]	2,300	12,900	4,000
H		0	0	0
Total	20,100	3,700	16,800	8,800
Layer	**Mixed Mesophytic**	**Chestnut Oak**	**Mixed Oak**	**Mixed Oak-Hardwood**
L	4,600	8,400	6,700	3,600
F	6,200	8,200	7,500	7,200[a]
H	0	0	0	
Total	10,800	16,600	14,200	10,800

TABLE I

WEIGHT OF THE UNINCORPORATED ORGANIC MATTER
UNDER EAST TENNESSEE FOREST STANDS (Continued)
(Pounds of organic matter per acre)

Layer	Oak-Hickory	White Oak
L	7,400	5,000
F	5,600	3,800[a]
H	0	
Total	13,000	8,800

[a]F and H.

The table mountain pine stand is second in accumulation with 26,200 pounds of forest floor organic matter with about 1½ times as much weight in the H layer as the total of the L and F layers. This is only 6,200 pounds more than was present under the scrub pine stand. The scrub pine stand ranks third in total organic matter followed by hemlock-hardwood which is somewhat surprising since the scrub pine is still in successional stages. In the case of the scrub pine, there is a fairly even distribution of accumulation of organic matter in the L and F-H layers of 10,000 pounds and 10,100 pounds respectively. This is also fairly true for the L and F layers under the deciduous stands. The hemlock-hardwood stand is a noticeable exception and has over three times as much organic matter accumulated in the F layer as the L layer and a total of 16,800 pounds per acre. The forest floor did not have an H layer and was underlain by a rather typical A_1 horizon. Under many other stands of hemlock with a dense Rhododendron understory humus accumulations have been observed. The hemlock-hardwood and oak-pine stands are roughly similar in total forest floor weights, the oak-pine totaling 14,100 pounds per acre, but very different in distribution of amounts in the L and F layers. The oak-pine is more like the deciduous stands in that the F and L amounts are fairly well balanced. The extreme of the deciduous stands was mixed oak-hardwood which has a ratio of 2:1 F and H over L. Four stands have higher weights for the L layer than the F layer and the other four are vice versa. At present generalizations about this could not be made without further study.

The range of the total organic matter of the forest floor in the deciduous stands, not including the hemlock-hardwood stand and the oak-pine stand, is from 6,000 pounds to 16,600 pounds per acre. The low weight under the beech gap is strikingly different than the adjacent spruce-fir stand. A high weight was present under chestnut oak as might have been expected from general observations of the canopy as a litter producing potential. The weights of the other deciduous stands were scattered between the high and low weights.

The stand with the lowest total organic matter in the forest floor was the red cedar stand with only 3,700 pounds per acre. This may be attributed to low litter fall and to rapid incorporation into the mineral horizons upon decomposition.

Total Organic Matter

Total organic matter was computed by multiplying the per cent organic matter (Tables IV-IX) times the weight of each horizon and the figures totaled (Table II). The totals do not include all soil to bed-rock but only to those depths collected. The relative depths to which samples were taken in the subsoil were not uniform so each total should be considered as a separate item.

Physical and Chemical Properties of Organic Layers and Mineral Horizons

The bulk density figures are presented in Table III. Generalizations that can be made from the raw data are few. The L layer under spruce-fir has the greatest density of all of the L layers. The stands of table mountain pine and scrub pine have .03 to .04 g./cc. higher values

TABLE II

WEIGHT OF THE TOTAL ORGANIC MATTER IN EAST TENNESSEE SOILS
(Pounds of organic matter per acre)

Layer	Spruce-Fir	Beech Gap	Table Mt. Pine	Oak Pine
L	4,600	2,100	6,800	7,800
F	13,600	3,900	3,800	6,300
H	69,200	0	15,500	0
A_1	57,800	36,900	0	45,300
A_2	0	0	18,700	0
A-B	32,100	37,000	20,200	0
B	45,400	42,100	27,800	18,100
Total	222,700	122,000	92,800	77,500

Layer	Scrub Pine	Red Cedar	Hemlock Hardwood	Mixed Hardwood
L	10,000	1,400	3,900	4,800
F	10,100[a]	2,300	12,900	4,000
H		0	0	0
A_1	12,200	64,500	52,300	66,600
A_2	0	0	0	0
A-B	0	0	0	0
B	16,100	119,000[b]	59,700	73,400
Total	48,400	187,200	128,800	148,800

TABLE II

WEIGHT OF THE TOTAL ORGANIC MATTER IN EAST TENNESSEE SOILS (Continued)
(Pounds of organic matter per acre)

Layer	Mixed Mesophytic	Chestnut Oak	Mixed Oak
L	4,600	8,400	6,700
F	6,200	8,200	7,500
H	0	0	0
A_1	47,300	27,700	42,500
A_2	0	0	0
A-B	0	0	0
B	63,500	32,900	43,600
Total	121,600	77,200	100,300

Layer	Mixed Oak Hardwood	Oak Hickory	White Oak
L	3,600	7,400	5,000
F	7,200[a]	5,600	3,800[a]
H	0	0	0
A_1	8,100	18,500	7,300
A_2	30,500	0	23,600
A-B	12,200	0	21,200
B	14,300	19,500	20,600
Total	75,900	51,000	72,700

[a]F and H.

[b]C horizon.

TABLE III

BULK DENSITIES OF LAYERS AND HORIZONS UNDER VARIOUS FOREST STANDS IN EAST TENNESSEE

Type	Layers			Horizons			
	L	F	H	A_1	A_2	A-B	B
Spruce-fir	0.12[a]	0.16	0.21 .29[b]	0.82	-	1.14	1.26
Beech gap	.01	.10	-	.87	-	1.18	1.17
Table Mt. Pine	.07	.09	.21	.73	-	.95	1.04
Oak-pine	.04	.10	-	1.08	-	-	1.31
Scrub pine	.08	.17[c]	-	.92	-	-	1.30
Red cedar	.05	.12	-	.75	-	-	1.12[d]
Hemlock-Hardwood	.03	.11	-	.50	-	-	.80
Mixed Hardwood	.04	.07	-	.63	-	-	.85
Mixed Mosophytic	.05	.09	-	.71	-	-	1.12
Chestnut oak	.04	.13	-	.66	-	-	.83
Mixed oak	.04	.10	-	.85	-	-	1.23
Mixed oak-hardwood	.02	.10[c]	-	.88	1.19	1.34	1.35
Oak-hickory	.04	.11	-	.94	-	-	1.35
White oak	.02	.11[c]	-	1.06	1.17	1.46	1.41

[a]g./cc.

[b]Lower $\frac{1}{4}$ of horizon.

[c]F and H.

[d]C horizon.

than most of the deciduous stands, which range from .01 to .05 g./cc. in the L layer. The bulk densities of the F layers are very similar, excepting that under the spruce-fir which is a little higher than the rest. In the rest of the horizons there is a general relationship between the mineral layer bulk density and the amount of organic matter present. Comparison of data in Table III and Tables VI-IX generally indicate that with a relative increase in organic matter there is a decrease in bulk density. The ranges of bulk densities are from 0.01 to 0.12 g./cc. in the L layer, from 0.07 to 0.17 in the F layer, from 0.21 to 0.29 in the H layer, from 0.50 to 1.08 in the A_1 horizon, from 1.17 to 1.19 in the A_2 horizon, from 0.95 to 1.46 in the AB horizon and from 0.80 to 1.41 in the B horizon collected.

The data of Tables IV-IX are shown graphically in Figures 1-14. Both the tables and graphs are an aid to the following discussion of the chemical properties of the profiles under the forest stands.

Comparisons of pH values under the spruce-fir are similar to those reported by Heimburger (1934) for a thick podsol in the Adirondacks of 3.0 and 3.4 for the H_1 and H_2 layers. There is also a favorable comparison (Cain 1931) for spruce-fir surface and subsoil values of 3.6 and 3.8 and Juniper woodland values of 7.9 and 7.9 for surface and subsoil respectively. The beech gap with pH values of 4.5 and 4.5 (Cain 1931) are only slightly higher than those found by the author of 4.1 and 4.3 for surface soil and subsoil. It has been shown (Cain 1931) that acidity of all horizons increases with altitude, and that surface soils are generally more acid than subsoils, which was found to be true in the present case at the higher elevations. Under all deciduous stands at lower elevations, the subsoils were at least slightly more acid than the surface with the opposite being true under coniferous stands, except for the scrub pine which had a gradient like the deciduous forest profiles.

It is felt that the important thing illustrated in Figures 1-14 is that values for not only carbon, but nitrogen, calcium and potassium are much higher in the forest floor materials than in any part of the mineral soils below. Such graphs illustrate the holding and concentrating effect of forest floor materials.

The calcium content is generally much lower in the forest floor and upper mineral soil under the stands of spruce-fir, beech gap, and table mountain pine than in the other stands studied. The forest floor and mineral soil of the beech gap are less extreme in calcium content and pH than the spruce-fir and the table mountain pine stands. The variation is not as pronounced in the B horizon as for those strata above it. Generalizing from the data for these stands at the higher elevations, one would suspect that the nutrient cycle is above the mineral soil. The significance of this statement, for those stands mentioned, is that the forest floor, rather than the mineral soil, is the storehouse of calcium. Thus these mature forests are in equilibrium with their forest floors. A similar situation also exists in the stands in the mountains over sandstone but the forest floor nutrients are intermediate in amounts between the stands at high elevations over graywacke and those at lower elevation over calcareous parent materials. From the above generalizations it may be concluded that calcium decreases in content with increase in elevation.

The potassium content does not conform well to any general trends.

The most abrupt changes to calcium and potassium with depth from forest floor to mineral soil occur over parent materials of graywacke, sandstone, and shale. Carbon and nitrogen usually decrease gradually with depth under mull humus types with more abrupt changes from forest floor to mineral soil occuring with the thin duff mull type.

C/N ratios are generally higher for forest floor materials under stands contributing conifer litter than under deciduous stands. In the mineral soil this trend disappears and there is wide variation among the stands. The ranges of C/N ratios are from 26.3 to 67.8 in the L layer, from 21.8 to 53.9 in the F layer, from 17.9 to 40.9 in the H layer, from 9.4 to 26.7 in the A horizon and from 9.7 to 27.0 in the B horizon.

TABLE IV

CHEMICAL PROPERTIES OF THE ORGANIC (L) LAYER
UNDER DIFFERENT FOREST STANDS

Type	Total Organic Matter Per Cent	Total Carbon Per Cent	Total Nitrogen Per Cent	C/N Ratio	Total Ca. m.e./100 g.	Total K m.e./100 g.
Spruce-fir	94.83	55.01	1.47	37.4	21.2	2.5
Beech gap	84.75	47.79	1.82	26.3	31.5	0.9
Table mt. pine	94.47	54.79	0.82	67.8	15.0	0.6
Oak-pine	89.85	52.12	0.77	67.7	65.0	1.6
Scrub pine	93.81	54.44	0.99	44.2	53.7	4.5
Red cedar	95.82	55.58	0.85	65.4	168.7	2.6
Hemlock-hardwood	87.95	51.62	1.28	40.3	64.3	4.4
Mixed hardwood	92.86	53.86	1.28	42.1	63.4	4.8
Mixed mesophytic	96.92	56.22	1.37	41.0	66.3	4.5
Chestnut oak	93.85	54.44	1.23	44.2	111.2	2.9
Mixed oak	87.09	50.52	1.22	41.4	90.0	2.4
Mixed oak-hardwood	92.91	53.89	1.47	36.6	86.3	2.9
Oak-hickory	93.85	54.44	0.99	54.9	115.0	5.0
White oak	95.35	55.31	1.20	46.1	105.0	2.3

TABLE V

CHEMICAL PROPERTIES OF THE ORGANIC (F) LAYER
UNDER DIFFERENT FOREST STANDS

Type	Total Organic Matter Per Cent	Total Carbon Per Cent	Total Nitrogen Per Cent	C/N Ratio	Total Ca m.e./100 g.	Total K m.e./100 g.
Spruce-fir	93.94	53.91	1.71	30.9	11.3	2.5
Beech gap	69.52	40.53	1.68	24.1	27.1	3.2
Table mt. pine	93.53	54.25	1.21	44.8	17.5	1.8
Oak-pine	67.86	39.37	0.73	53.9	43.8	3.4
Scrub pine[a]	50.40	29.23	0.93	31.4	28.7	10.2
Red cedar	69.17	40.20	1.13	35.6	165.0	5.7
Hemlock-hardwood	80.82	46.88	0.99	47.3	23.2	3.5
Mixed hardwood	76.54	44.39	1.11	39.9	43.7	7.9
Mixed mesophytic	92.53	53.67	1.17	45.8	70.0	3.2
Chestnut oak	82.39	47.79	2.19	21.8	110.0	1.9
Mixed oak	77.58	45.00	1.02	44.1	58.8	3.1
Mixed oak-hardwood[a]	78.74	45.67	1.40	32.6	95.0	2.6
Oak-hickory	61.58	35.72	1.36	26.3	72.5	11.5
White oak[a]	76.80	44.55	1.20	37.1	72.5	1.0

[a]F and H layers.

TABLE VI

CHEMICAL PROPERTIES OF THE ORGANIC (H) LAYER
UNDER DIFFERENT FOREST STANDS

Type	Total Organic Matter Per Cent	Total Carbon Per Cent	Total Nitrogen Per Cent	C/N Ratio	Total Ca m.e./100 g.	Total K m.e./100 g.	pH
Spruce-fir	82.84	48.05	1.93	24.9	22.5	2.6	3.4
a	41.36	23.99	1.34	17.9	2.5	2.9	3.2
Table mt. pine	69.94	40.57	0.99	40.9	6.7	2.8	3.8
Scrub pine[b]	50.39	29.23	0.93	31.43	28.7	10.2	5.4
					Available Ca, m.e./100 g.	Available K, m.e./100 g.	
Spruce-fir					16.0	2.4	
a					1.3	0.55	
Table mt. pine					3.8	0.98	
Scrub pine[b]					17.3	1.4	

[a]Lower $\frac{1}{4}$ of spruce-fir horizon.

[b]F and H layer.

TABLE VII

CHEMICAL PROPERTIES OF THE MINERAL (A) HORIZON
UNDER DIFFERENT FOREST STANDS

Type	Total Organic Matter Per Cent	Total Carbon Per Cent	Total Nitrogen Per Cent	C/N Ratio	Available Ca, m.e./ 100 g.	Available K, m.e./ 100 g.	pH
Spruce-fir	18.98	9.99	0.56	17.7	0.5	0.24	3.4
Beech gap	9.48	4.99	0.53	9.4	1.9	0.53	4.1
Table mt. pine	14.40	7.58	0.34	22.2	0.7	0.45	4.1
Oak-pine	7.88	4.15	0.28	14.8	13.7	0.51	5.9
Scrub pine	8.24	4.34	0.22	19.7	10.3	0.80	5.4
Red cedar	23.45	12.34	0.64	19.3	54.2	0.40	7.4
Hemlock-hardwood	18.83	9.91	0.61	16.2	4.5	0.55	4.0
Mixed hardwood	14.06	7.40	0.46	15.7	4.6	0.29	5.2
Mixed mesophytic	17.73	9.33	0.51	18.3	7.5	0.53	4.7
Chestnut oak	13.28	6.99	0.60	11.6	30.1	1.15	6.9
Mixed oak	11.69	6.15	0.23	26.7	7.5	0.32	5.6
Mixed oak-hardwood	9.41	4.95	0.30	16.5	6.3	0.61	5.2
A-2	5.76	3.03	0.13	23.3	1.7	0.44	4.8
Oak-hickory	10.55	5.55	0.31	17.9	15.3	0.85	5.6
White oak	6.95	3.66	0.31	11.8	8.1	0.50	5.3
A-2	5.15	2.71	0.14	19.3	3.0	0.19	4.8

TABLE VIII

CHEMICAL PROPERTIES OF THE MINERAL INTERGRADING AB HORIZON
UNDER DIFFERENT FOREST STANDS

Type	Total Organic Matter Per Cent	Total Carbon Per Cent	Total Nitrogen Per Cent	C/N Ratio	Available Ca, m.e./ 100 g.	Available K, m.e./ 100 g.	pH
Spruce-fir	9.22	4.85	0.28	17.3	0.13	0.06	3.5
Beech gap	6.91	3.64	0.29	12.5	0.36	0.33	4.0
Table mt. pine	7.92	4.17	0.13	32.1	0.25	0.26	4.5
Mixed oak-hardwood	2.93	1.54	0.11	14.0	0.9	0.35	4.7
White oak	4.07	2.14	0.12	17.8	1.8	0.18	4.7

TABLE IX

CHEMICAL PROPERTIES OF THE MINERAL (B) HORIZON UNDER DIFFERENT FOREST STANDS

Type	Total Organic Matter Per Cent	Total Carbon Per Cent	Total Nitrogen Per Cent	C/N Ratio	Available Ca, m.e./ 100 g.	Available K, m.e./ 100 g.	pH
Spruce-fir	7.23	2.89	0.15	19.3	0.25	0.19	3.8
Beech gap	5.80	2.32	0.23	10.1	1.09	0.33	4.3
Table mt. pine	6.53	2.61	0.11	23.7	0.12	0.32	4.5
Oak-pine	2.93	1.17	0.12	9.7	5.3	0.10	5.6
Scrub pine	4.50	1.80	0.11	16.4	5.1	0.42	4.9
Red cedar[a]	20.07	8.03	0.45	17.8	43.0	0.30	7.7
Hemlock-hardwood	13.85	5.54	0.23	24.1	1.1	0.16	4.1
Mixed hardwood	12.76	5.11	0.24	21.3	0.75	0.44	4.9
Mixed mesophytic	13.03	5.21	0.34	15.3	1.2	0.16	4.5
Chestnut oak	9.10	3.64	0.27	13.5	12.4	0.92	6.8
Mixed oak	8.10	3.24	0.12	27.0	1.0	0.32	5.1
Mixed oak-hardwood	2.60	1.04	0.06	17.3	0.5	0.34	4.6
Oak-hickory	6.40	2.56	0.18	14.2	7.9	0.63	4.7
White oak	3.28	1.31	0.08	16.4	0.9	0.13	4.6

[a]C horizon.

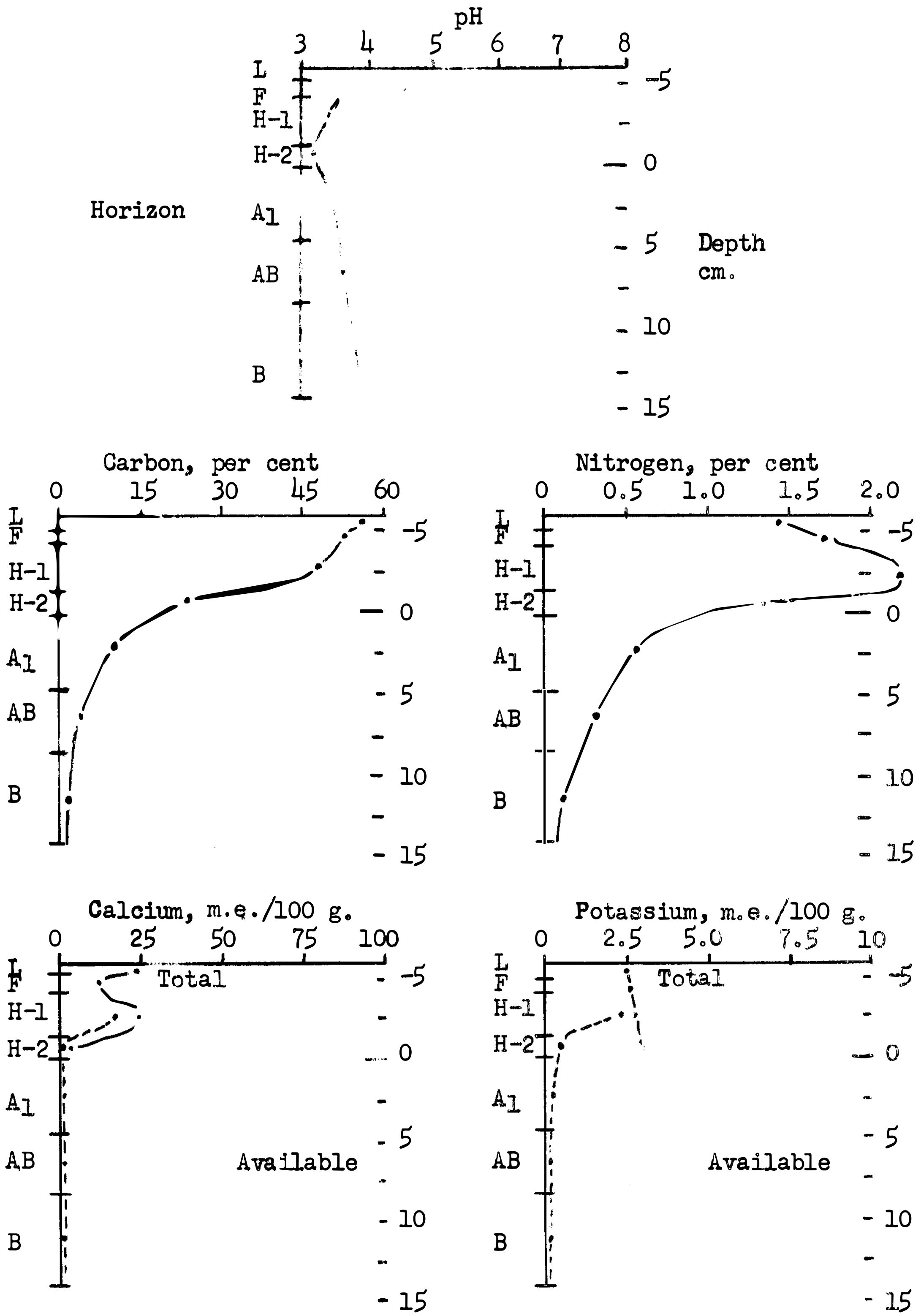


Figure 1. Results of Spruce-Fir Forest Floor and Soil Analysis.

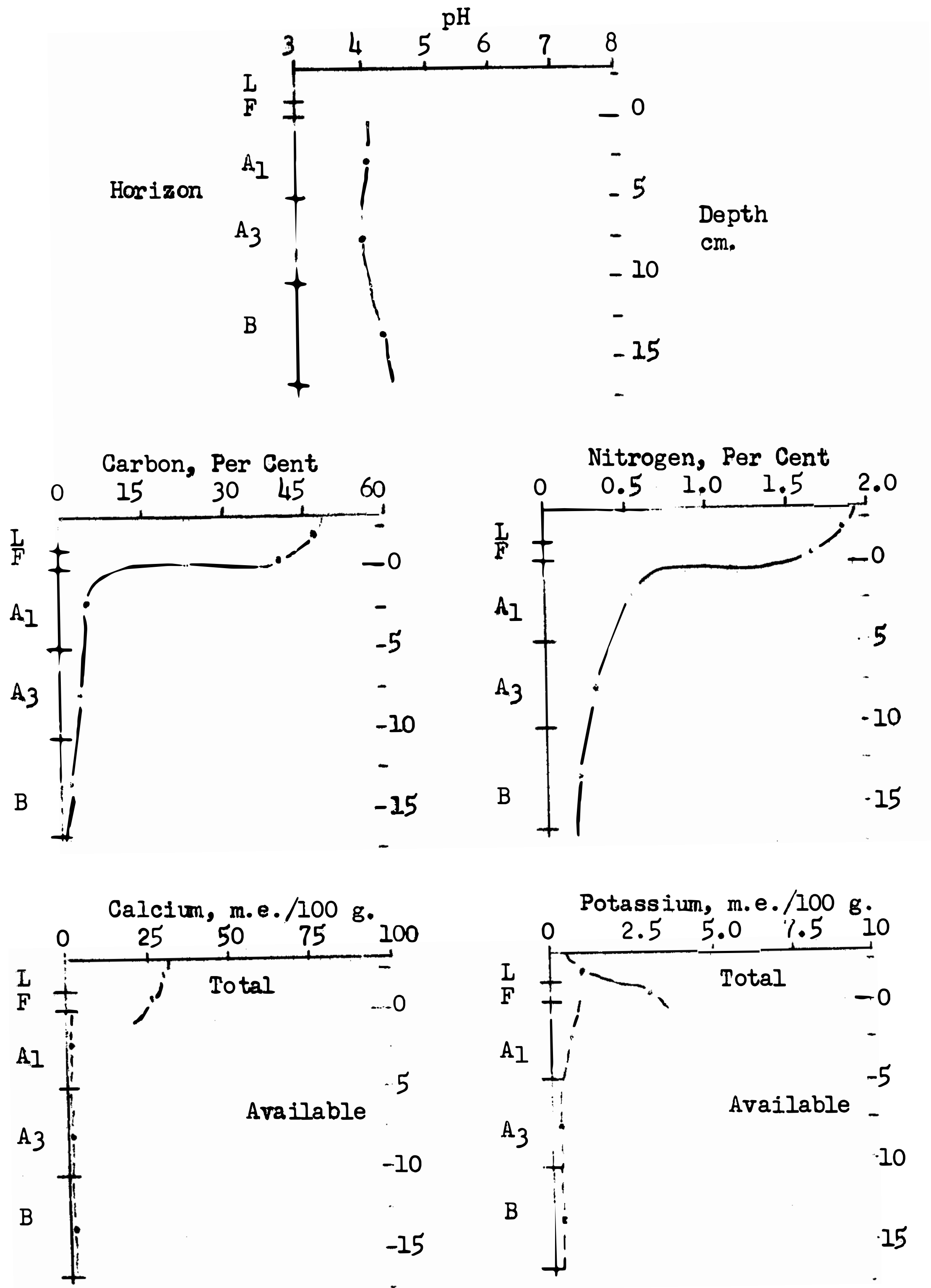


Figure 2. Results of Beech Gap Forest Floor and Soil Analysis.

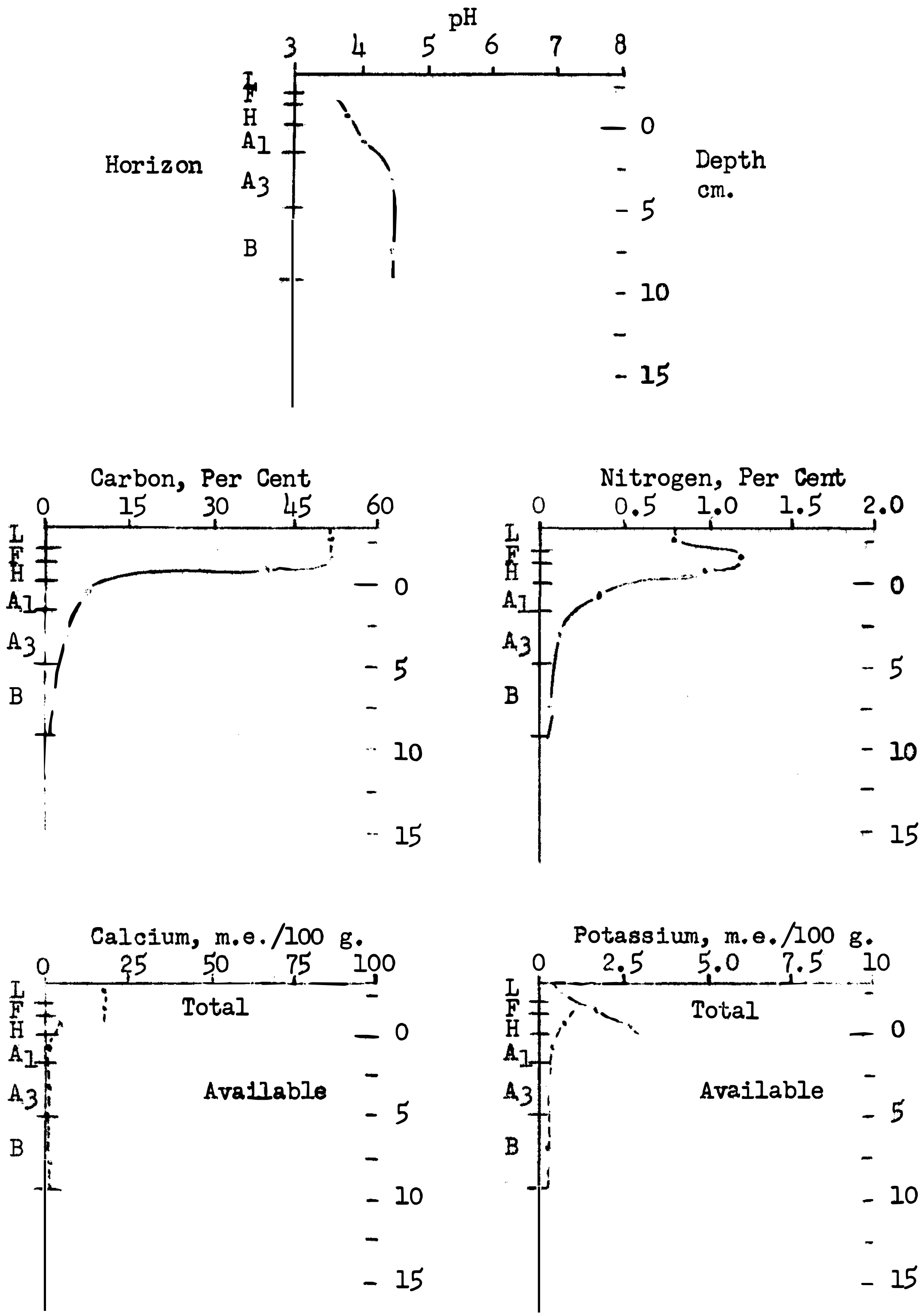


Figure 3. Results of Table Mt. Pine Forest Floor and Soil Analysis.

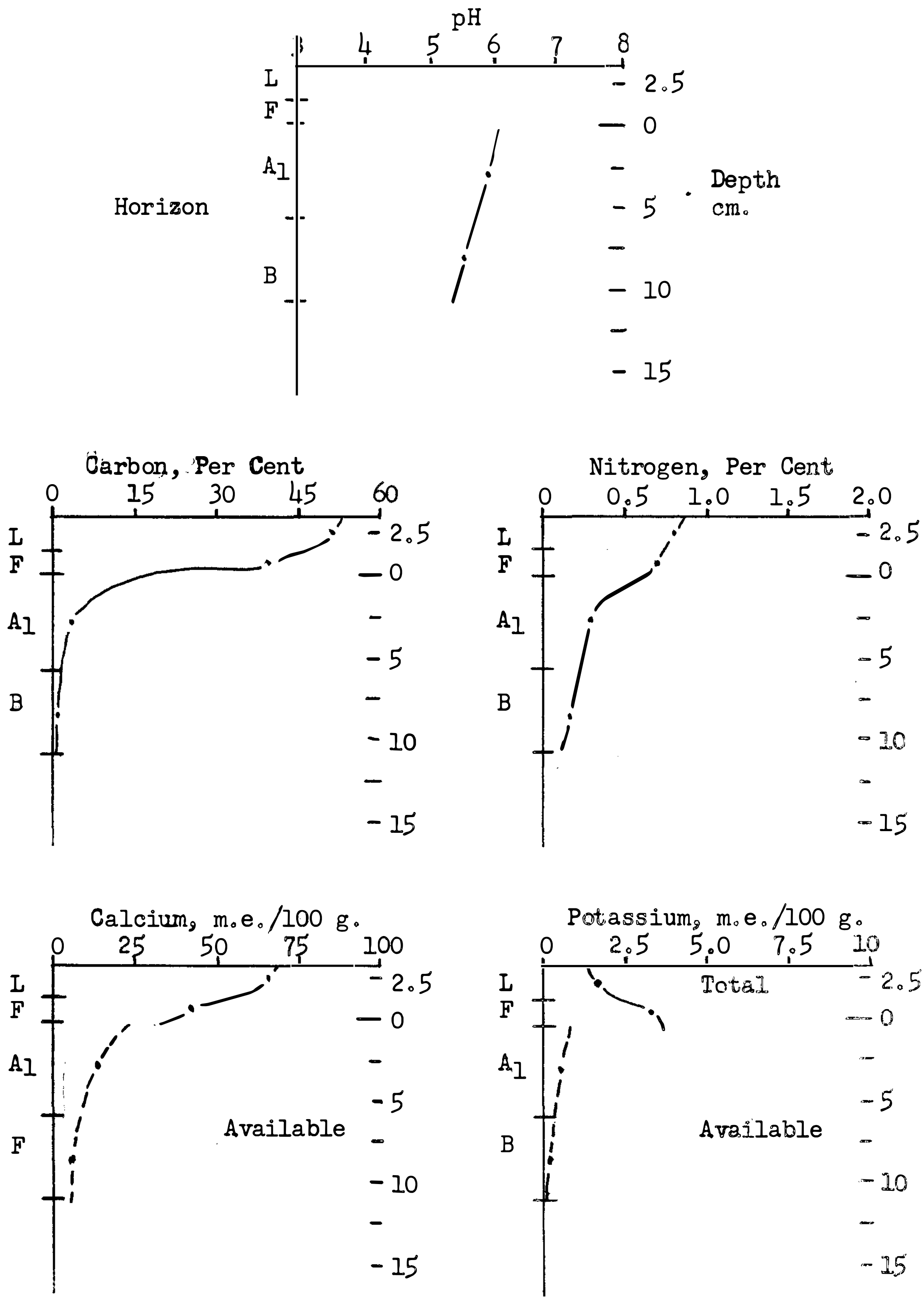


Figure 4. Results of Oak-Pine Forest Floor and Soil Analysis.

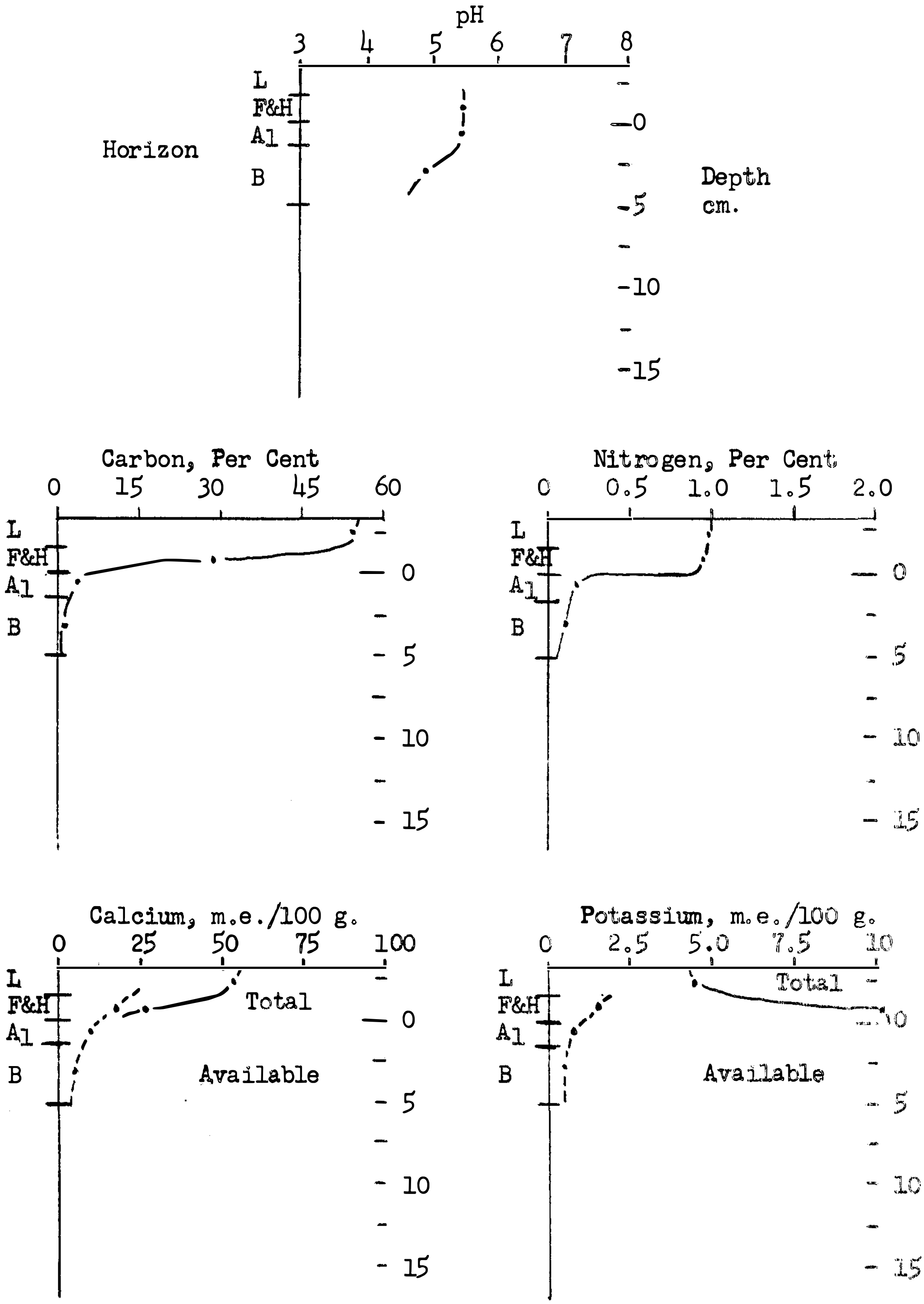


Figure 5. Results of Scrub Pine Forest Floor and Soil Analysis.

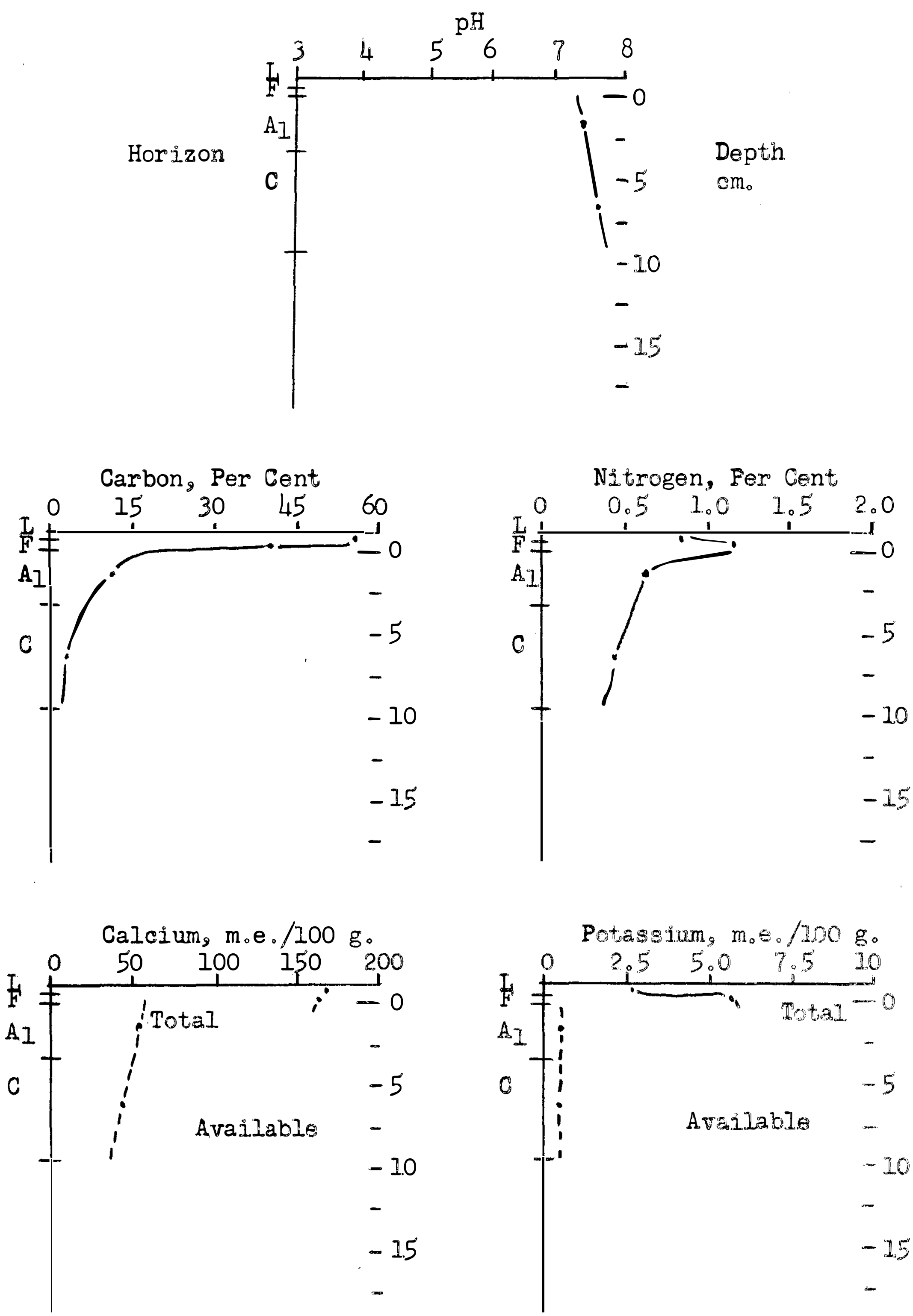


Figure 6. Results of Red Cedar Forest Floor and Soil Analysis.

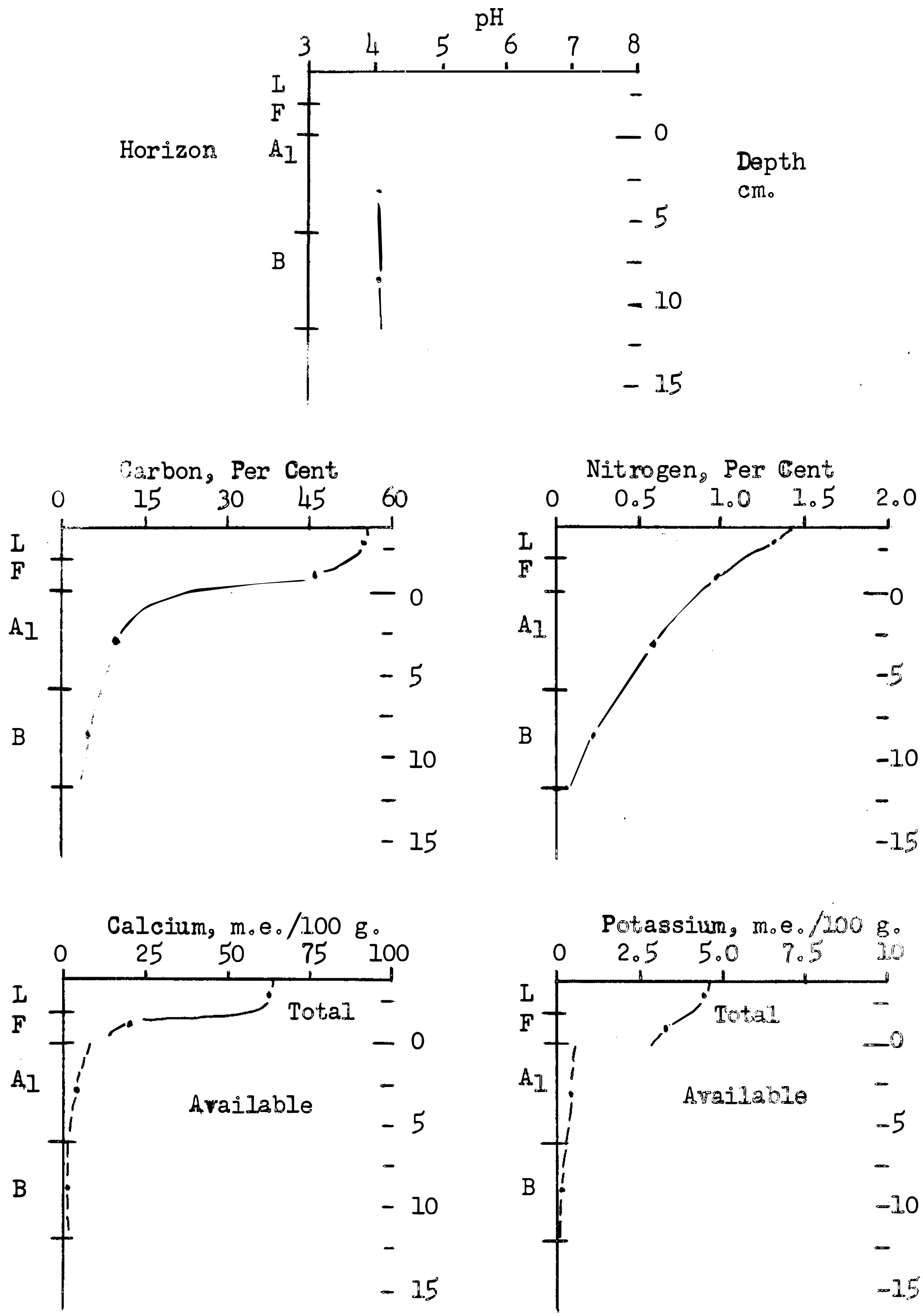


Figure 7. Results of Hemlock-Hardwood Forest Floor and Soil Analysis.

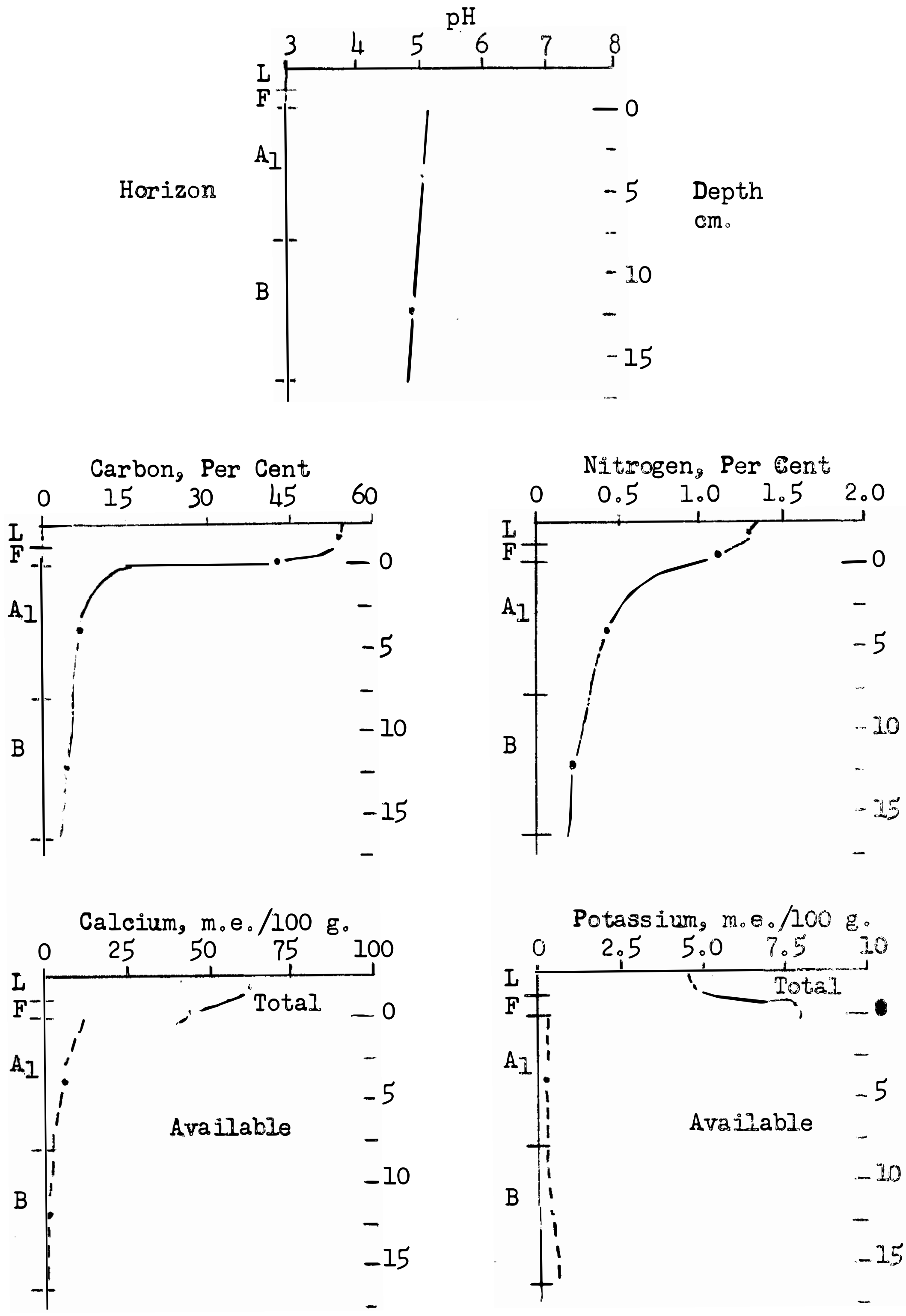


Figure 8. Results of Mixed Hardwood Forest Floor and Soil Analysis.

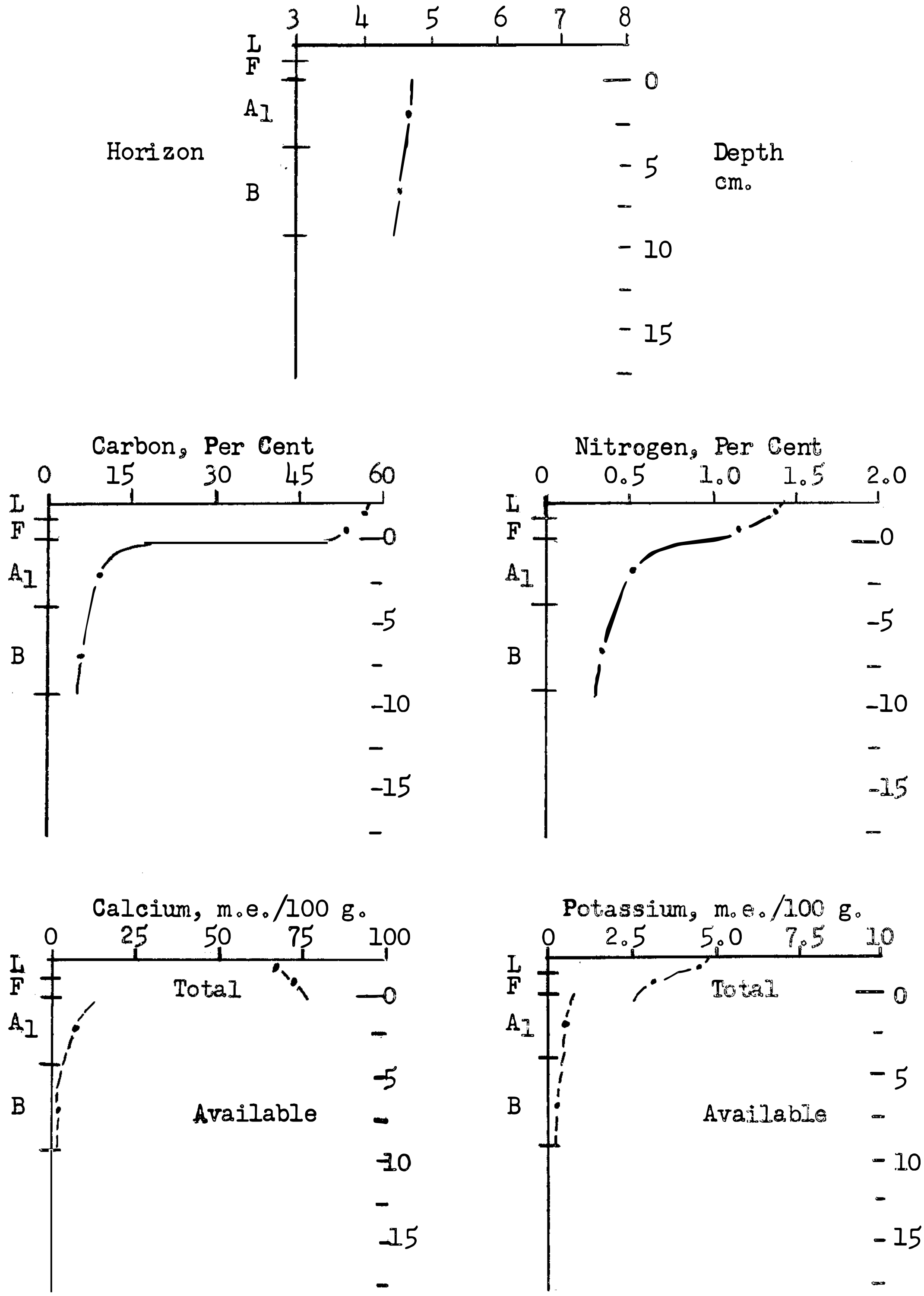


Figure 9. Results of Mixed Mesophytic Forest Floor and Soil Analysis.

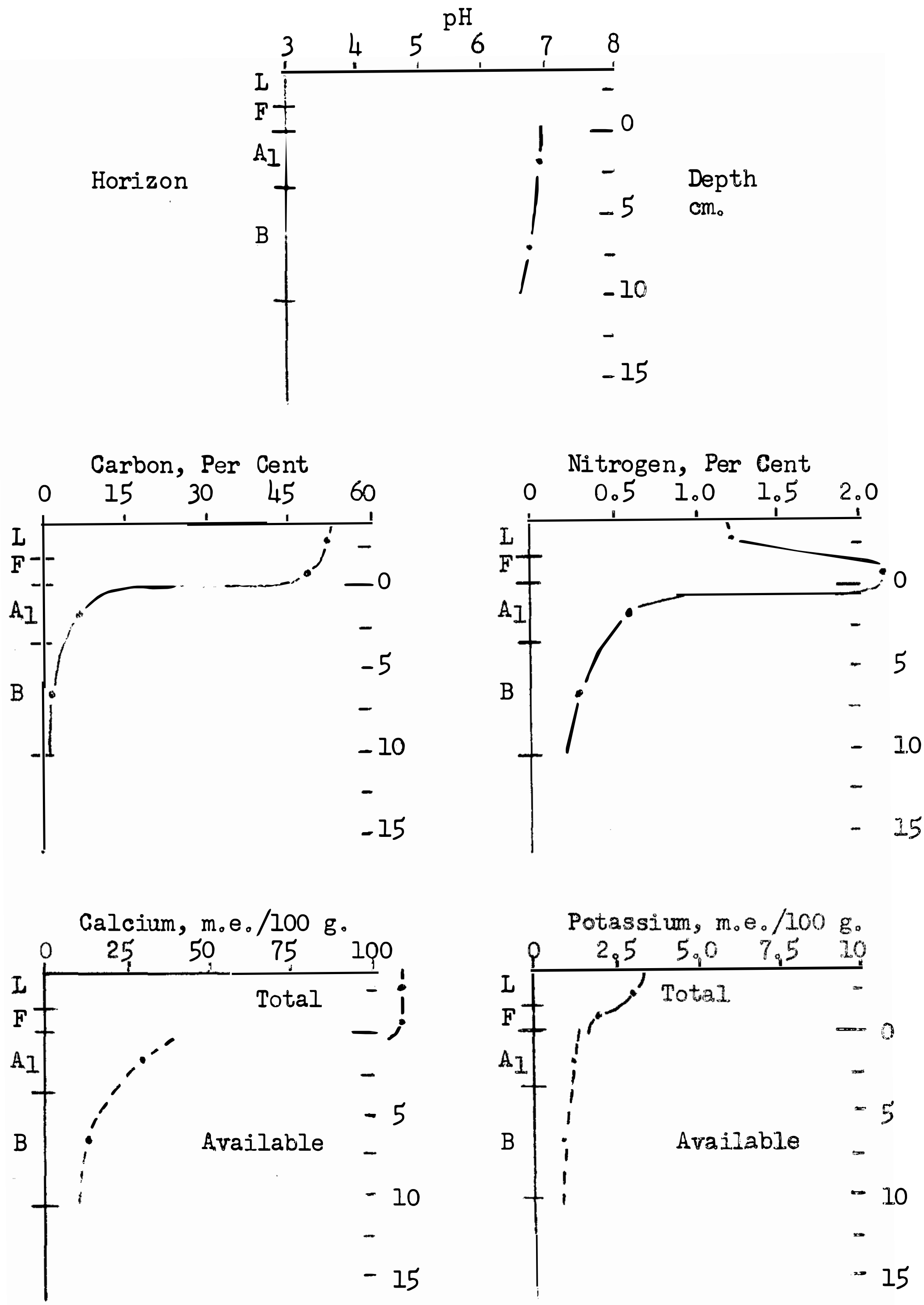
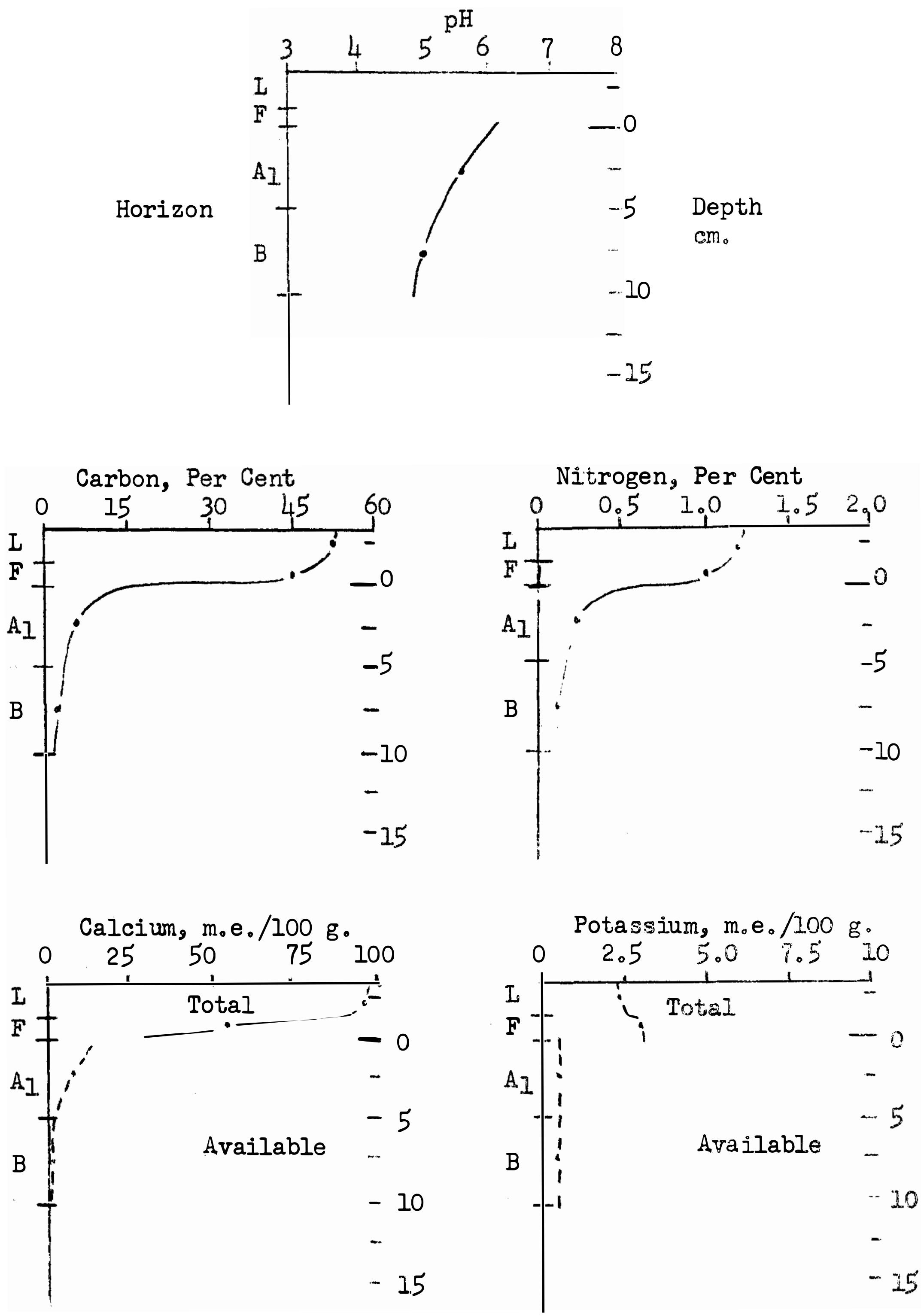


Figure 10. Results of Chestnut Oak Forest Floor and Soil Analysis.



Forest 11. Results of Mixed Oak Forest Floor and Soil Analysis.

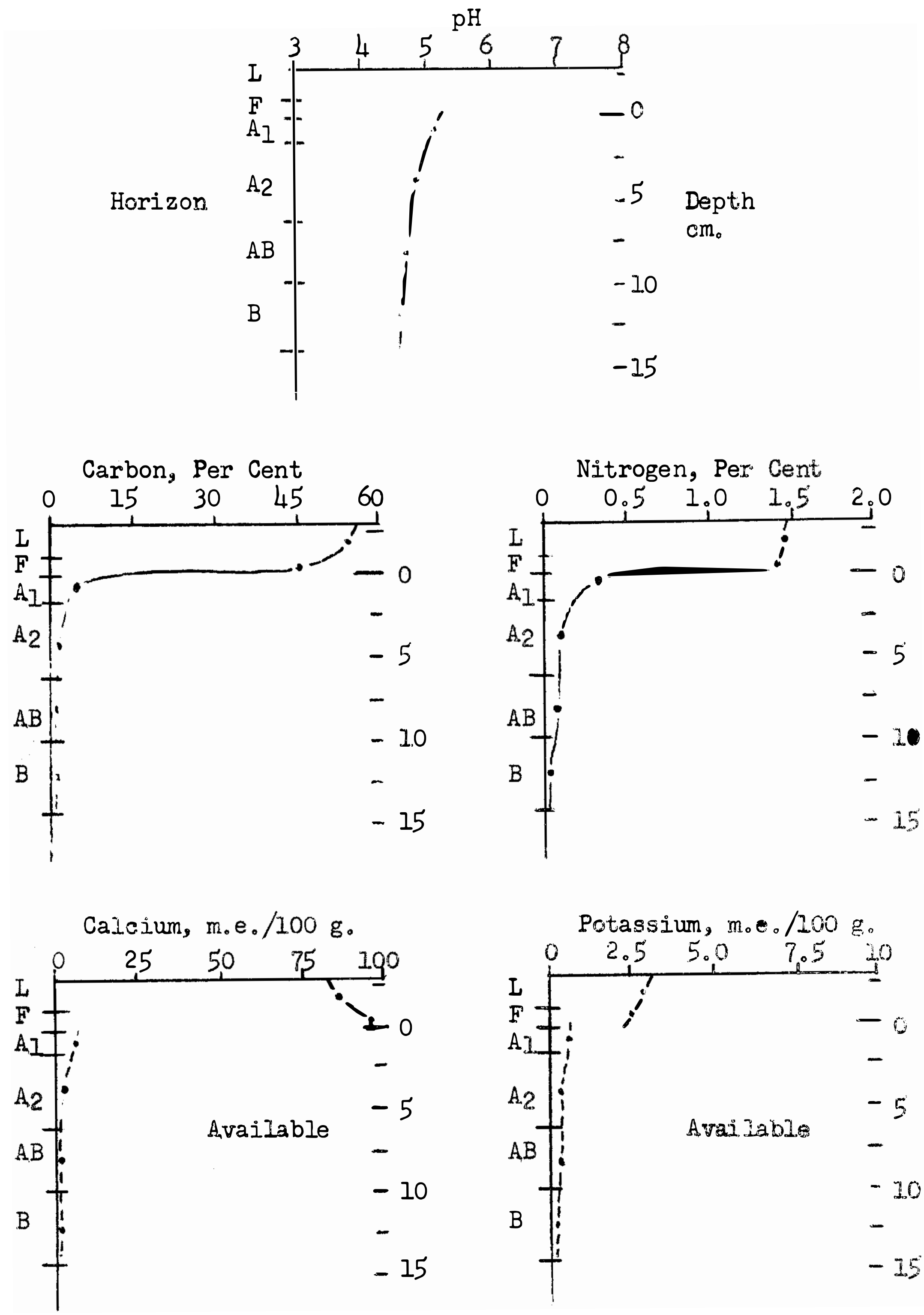


Figure 12. Results of Mixed Oak-Hardwood Forest Floor and Soil Analysis.

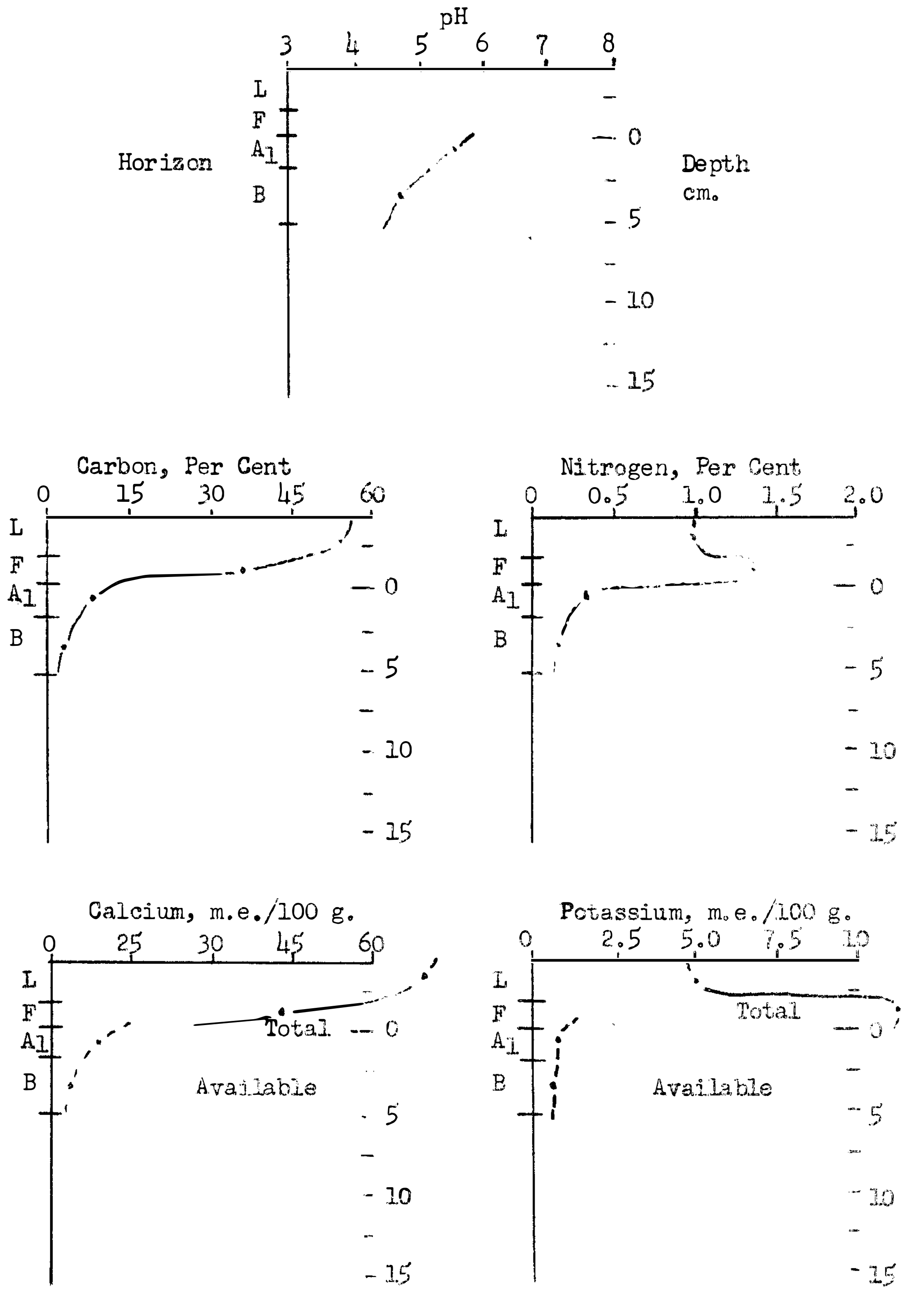


Figure 13. Results of Oak-Hickory Forest Floor and Soil Analysis.

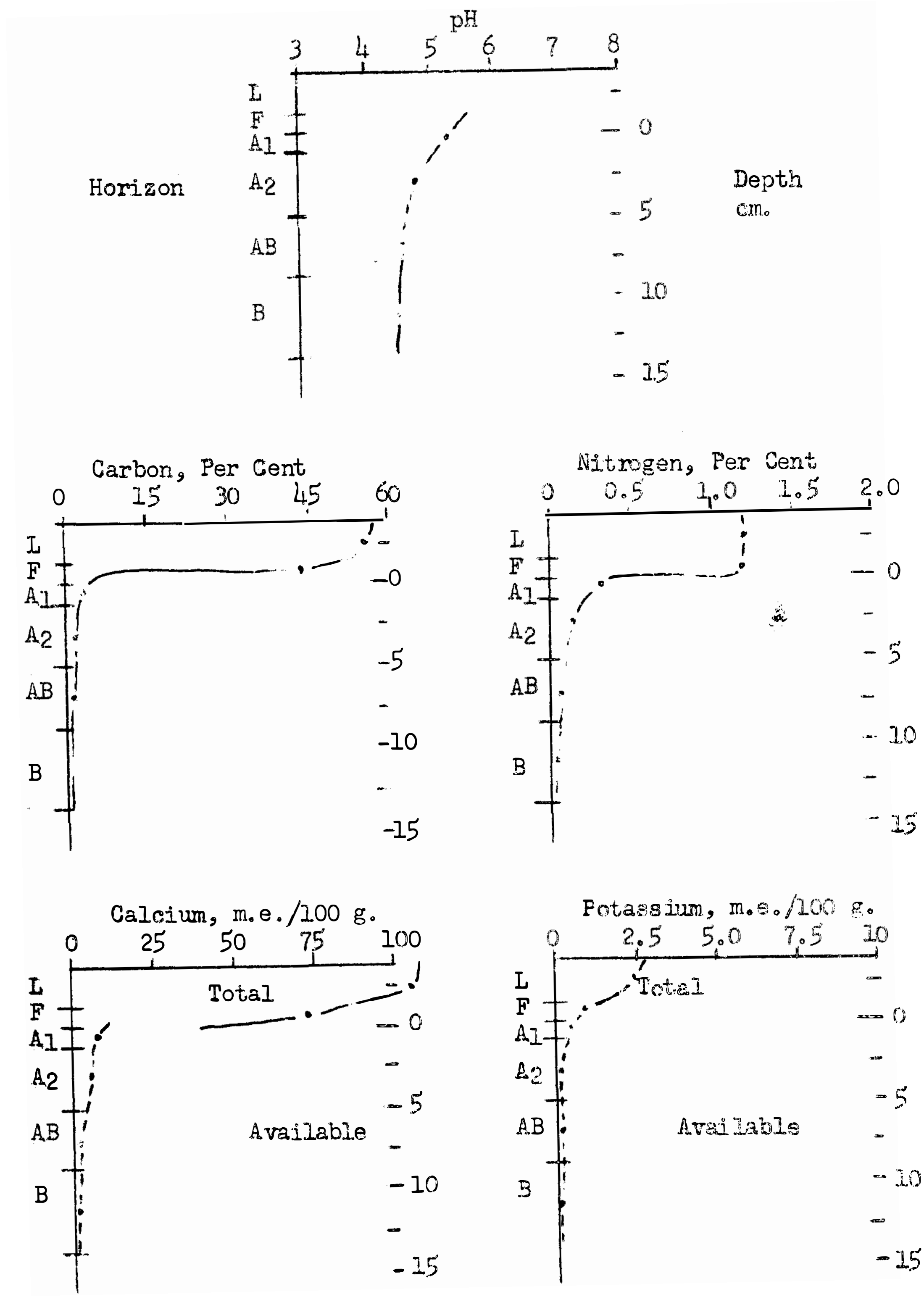


Figure 14. Results of White Oak Forest Floor and Soil Analysis.

Humus Types

Hoover and Lunt's (1952) key for classification of forest humus types has been applied to the present data using the profiles described earlier and the organic matter figures of Tables IV to IX. The resulting assignments are listed in Table X. Some explanation of why some stands were so classified is necessary. The assignment of two humus types to the spruce-fir stand were necessary because of distinct differences in the upper and lower part of the H layer. The upper part was felty as the classification implies while the lower part was very slick and greasy. Some question may arise since the lower part of the H layer is much lower in organic matter than the upper part but it is felt that the percentage of organic matter is high for A horizon.

The soils of the beech gap adjacent to the spruce-fir show characteristics of being an acid brown soil while under the spruce the soil was more nearly a weak podsol.

The humus type under the table mountain pine could not be considered a mor because of a rather high amount of organic matter present in the A horizon.

All of the other humus types fit the key of Hoover and Lunt very well although there was some doubt about the mixed-oak hardwood and the white oak stands. Both stands are on soils of the Red-Yellow Podzolic Great Soil Group but the F and H layers were very thin.

Generalizations that might be made are that humus types in east Tennessee under upland hardwood forest types on well developed Red-Yellow Podzolic soils are probably thin duff mulls, bearing in mind that under

TABLE X

HUMUS TYPES UNDER DIFFERENT FOREST STANDS

Stand Type	Humus Type
Spruce-fir	Felty mor
a	Greasy mor
Beech gap	Medium mull
Table mt. pine	Thin duff mull
Oak-pine	Medium mull
Scrub pine	Thin duff mull
Red cedar	Medium mull
Hemlock-hardwood	Medium mull
Mixed hardwood	Medium mull
Mixed mesophytic	Medium mull
Chestnut oak	Coarse mull
Mixed oak	Medium mull
Mixed oak-hardwood	Thin duff mull
Oak-hickory	Medium mull
White oak	Thin duff mull

[a]Lower $\frac{1}{4}$ of H horizon.

mesic conditions of heavy litter yield with rapid decomposition and incorporation the humus type may then be a medium mull. Also if the soil under a stand is similar in character to the Reddish Brown Lateritic Great Soil Group, for instance the Dewey Series, again the humus type may be a medium mull or even a coarse mull. In the Smoky Mountains at high elevations under a spruce-fir canopy, mor humus types may occur widely. Also in the Smoky Mountains the humus type under beech gap, mixed hardwood, mixed mesophytic and in this case hemlock-hardwood on soils similar to the brown forest soils (Coile 1938), medium mull will probably also be present. Careful observations should precede the determination of a humus type because of considerable variation in character and the difficulty of detecting the L, F and H layers, as other workers have reported (Oosting and Billings 1951).

The humus types present with lithosolic soils will probably be dependent on the type of vegetation stand present and also the character of the parent material.

VI. SUMMARY

An analysis of the forest floor layers and mineral soil horizons under 14 kinds of forest stands in east Tennessee was made. Forest floor and soil horizons, have been described as they occurred under both coniferous and deciduous stands at high and low elevations. Laboratory analyses for carbon, nitrogen, calcium, potassium, and pH were made. From the laboratory data and field observations total organic matter on the forest floor, total organic matter, bulk densities, forest floor and soil profiles, C/N ratios and humus types were described.

A study was made of the annual litter deposition for a coniferous and deciduous forest stand. The average annual litter fall of oven dry matter was 4,000 pounds per acre for a scrub pine stand and 4,450 pounds for an oak-hickory stand.

Total organic matter on the forest floor under a spruce-fir stand was 87,400 pounds per acre with all other stands having much less. The range under the deciduous forests was from 6,000 to 16,600 pounds per acre. Total organic matter under stands of scrub pine and table mountain pine ranged from 20,100 to 26,200 pounds per acre. Mixed coniferous-deciduous stands of hemlock-hardwood and oak-pine ranged from 14,100 to 16,800 pounds per acre. The stand with the lowest accumulation on the forest floor was red cedar with 3,700 pounds of organic matter per acre.

Total organic matter of the forest floor and mineral soil range from 51,000 to 222,700 pounds per acre under oak-hickory and spruce-fir respectively. The values in most cases do not represent all of the organic matter in the soil since collections were rarely made to bedrock.

It was found that pH and total calcium decrease markedly with an increase in elevation. Also at higher elevations the storehouse of calcium is almost restricted to the forest floor. Trends with elevation for potassium content were not as evident as those for calcium.

The humus types present under the east Tennessee forest stands studied varied with stand type, soil type and parent material. The humus types present were:

1. Felty-greasy mor. Present under a spruce-fir stand on Graywacke parent material at 5200 feet elevation.

2. Thin duff mull. Present under stands of table mountain pine and scrub pine on shale parent material, also under mixed oak-hardwood and white oak stand on well developed Red-Yellow podzolic soils on cherty limestone parent material.

3. Medium mull. Medium mull was the most common humus type present. It was present under stands of a beech-gap on local colluvium from graywacke, oak-pine, mixed oak and oak-hickory on cherty limestone parent material, and hemlock-hardwood, mixed hardwood and mixed mesophytic on sandstone parent material.

4. Coarse mull. Present under a stand of chestnut-oak on Dewey soil type over limestone parent material.

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APPENDIX

PROCEDURES USED IN LITTER AND SOIL ANALYSIS

The Plant and Soil analyses were run in the University of Tennessee Botany Department laboratories, the University of Tennessee Agricultural Experiment Station in Knoxville, and the University of Tennessee Dairy Department laboratory.

Samples of oven-dry litter and humus materials were weighed and ground in a Wiley Mill through a 40 mesh screen. The samples of oven-dry soil were weighed and ground and passed through a two millimeter sieve.

pH

Distilled water was added to a portion of the humus or soil and stirred until it became paste-like. The sample was then allowed to set for a few minutes before it was again stirred and determinations were made on a model G Beckman pH Meter.

Exchangeable Calcium and Potassium

To a ten gram sample of oven-dry humus or soil 50 ml. of neutral normal ammonium acetate were added. The mixture was then shaken for thirty minutes on an automatic shaker and set aside over-night. On the following morning the sample was again shaken for thirty minutes. The sample was filtered through a Whatman's No. 42 filter paper in a Buchner funnel and washed with 200 ml. of the ammonium acetate reagent. A small portion (about 5 ml.) of the filtrate was then tested for calcium and potassium on a Beckman DU flame spectrophotometer equipped with a photo-multiplier attachment. Wave lengths of 442.7 for calcium and 766.5 for potassium were used. Sample readings were compared with calibration

calibration curves obtained from standard solutions and the calcium and potassium content were calculated in parts per million. The data was then converted to me./100 g. by the formula:

$$\text{me. Ca/100 g.} = \frac{\text{ppm.} \times 25 \times 100}{.020}$$

and

$$\text{me. K/100 g.} = \frac{\text{ppm.} \times 25 \times 100}{.039}$$

<u>Total</u> <u>Calcium</u> <u>and</u> <u>Potassium</u>

To a 0.5 gram sample of non-mineral material (L, F, and H layers independently), 5 ml. of concentrated nitric acid were added and the mixture heated to dryness. To this, 5 ml. of a 1:1 nitric acid and water, and 5 ml. of percloric acid were added and again the materials heated to dryness, repeating if necessary. Then 5 ml. of 1:1 hydrocloric acid and water were added-to dissolve the mineral crystals-and the solution heated slightly. The solution was then filtered through Whatman's No. 42 filter paper and the container and filter were rinsed with distilled water. The filtrate was then diluted to 250 ml. These solutions were run, as were the exchangeable calcium and potassium, on a Beckman flame spectrophotometer using standards of calcium and potassium in distilled water and hydrocloric acid. Concentration in parts per million were obtained and recalculated to me./100 g. by these formulas:

$$\text{Ca me./100 g.} = \frac{\text{ppm.} \times 500 \times 100}{.020}$$

and

$$\text{K me./100 g.} = \frac{\text{ppm.} \times 500 \times 100}{.020}$$

Total Carbon and Organic Matter

To 0.0500 g. of nonmineral materials (L, F, and H layers independently), 0.500 g. of A horizon soil, and 1.00 g. of B horizon soil, all oven dried, (with the mineral soil having been sieved through a 0.2-mm nonferrous sieve) exactly 10 ml. of 1 N. potassium bicromate were added and the suspension mixed gently. Then 20 ml. of concentrated sulfuric acid were added rapidly and mixed gently for one minute. This mixture was allowed to stand for thirty minutes. Samples without soil were run parallel daily. The solution was then diluted with 200 ml. of distilled water and 10 ml. 85 per cent phosphoric acid, 0.2 g. sodium fluoride, and 4 or 5 drops of 0.25 M. orthophenanthroline indicator solution were added. The solution was back titrated with 0.5 N. ferrous sulfate solution delivered from a buret. The color change is from green to red with a one drop end point. The results for per cent total carbon and per cent total organic matter were calculated by the equations:

for factor,

$$\text{Factor} = \frac{12}{4000} \times \frac{100}{R}$$

for per cent total carbon

$$\text{per cent total carbon} = \frac{10\left(1-\frac{T}{S}\right) \times \text{factor}}{\text{g.}}$$

For L, F, and H layers (R) the recovery factors used were; 0.77 in the case of deciduous forests and 0.70 for coniferous forests. For all mineral horizons, 0.74 was used. Per cent total organic matter was obtained by multiplying the per cent total carbon by 1.724 for all nonmineral horizons, 1.9 for A and AB horizons and 2.5 for B and C horizons.

<u>Per</u> <u>cent</u> <u>Total</u> <u>Nitrogen</u>

1.00 g. of L, F, H, and A_1 horizons, 5.00 g. of AB and B horizons that were oven-dried and sieved through a 0.5-mm. sieve and placed in a 800-ml. Kjeldahl digestion flask. Then 20 g. of sodium sulfate-plus-catalyst digestion mix were added to each. To this 25 ml. of concentrated sulfuric acid were added and mixed gently. About 30 ml. of distilled water was added to each of the samples of mineral soil before the addition of the sulfuric acid. The flasks were then placed on the digestion rack over low heat until frothing stopped. Then the heat was increased until the condensation of the acid reached approximately one-third the way up the neck on the digestion flask. The digestion proceeded for at least three hours. The longer than normal digestion was necessary to decompose the more resistant compounds present in the mineral soil. At the end of the period of digestion the solution was permitted to cool somewhat and 200 ml. of distilled water were added, followed by further cooling. When the flask and solution were cooled to room temperature or below, 75 ml. of 40 per cent sodium hydroxide and a few pieces of mossy zinc were added. The resulting ammonia was then distilled into 25 ml. of 4 per cent boric acid containing methylene blue-methyl red indicator. The boric acid was then backtitrated with 0.1 N. hydrocloric acid. The formula for calculation of per cent nitrogen in soil or plant tissue is:

$$\text{per cent N} = (T-B) \times N \times \frac{1.4}{S}$$

in which

T = sample titration, ml. standard acid

B = blank titration, ml. standard acid

N = normality of standard acid

S = sample weight in grams.

KEY FOR THE CLASSIFICATION OF FOREST HUMUS TYPES

The following humus classification system was developed by the Committee on Forest Humus Classification, Forest Soils Subdivision, Soil Science Society of America (Hoover and Lunt 1952). Thus it replaces the earlier humus classification of (Heiberg and Chandler 1941) on which it was built.

A. No H layer; A_1 horizon an intimate mixture of organic matter and mineral soil, with gradual transition between the A_1 and the horizon beneath. F layer may or may not be present. . . . . <u>Mull</u>

1. A_1 essentially single-grain or massive, without aggregates. Organic matter appears to be more or less uniformly distributed throughout.

   (a) Massive and firm with generally less that 5% organic matter by weight. . . . . <u>Firm Mull</u>

   (b) Loose, with low to medium organic matter content (usually less than 10%) and consisting of a mixture of mineral soil and organic matter as single grains. Typically on sandy soils. . . . . <u>Sand Mull</u>

2. A_1 horizon, granular or crumb structure. Concentration of organic matter and the granular structure most pronounced in the upper A_1 and decrease gradually with depth.

   (a) Coarse granular or crumb structure; many granules 1/8" (2-3mm) or larger. Usually 5-20% organic matter. . . . . <u>Coarse Mull</u>

   (b) Medium granular or crumb structure; larger granules about 1/16" (2mm.) or slightly smaller. Wide range of organic matter content, usually 5-30%. . . <u>Medium Mull</u>

   (c) Fine granular structure; frequently has the appearance fine black sawdust; organic matter content high, usually over 30%. . . . . <u>Fine Mull</u>

3. Complex mull types. Distinct structural differences between layers within the zone of organic matter incorporation.

(a) Fine mull underlain by coarse or medium mull. . . Twin Mull

B. H and F layers present with an underlying A_1 horizon essentially similar to that of a true mull. Gradual transition from the H to A_1 and mineral soil beneath. (This type possesses some of the characteristics of both mulls and mor). . . . . .Duff Mull

1. Combined F and H layers more than 1 inch thick. .Thick Duff Mull

2. Combined F and H layers less than 1 inch thick. . Thin Duff Mull

C. H layer present (except in 3 below). Practically no mixing of organic matter with mineral soil. Abrupt transition from surface organic matter to underlying horizon. . . . . Mor

1. The H layer more than 1/2 inch thick. . . . . Thick Mor

(a) The H layer has a fince granular structure. . .Granular Mor

(b) H layer structureless, feels greasy when wet but hard and brittle when dry. . . . . Greasy Mor

(c) H layer feels and looks felty, due to presence of fungal hyphae and/or plant residues but not living roots. . . . . Felty Mor

2. H layer less than 1/2 inch in thickness. . . . . Thin Mor

3. H layer lacking or present only as a thin film in depressions. . . . . .Imperfect Mor

DEFINITIONS

L layer - (Litter) the surface layer of the forest floor consisting of freshly fallen leaves, needles, twigs, stems, bark and fruits. Where decomposition and incorporation are rapid, this layer may be very thin or absent during the growing season. In standardized horizon nomenclature this is the A_{00} horizon.

F layer - A layer of partially decomposed litter still recognizable as to origin. The A_{01} horizon.

H layer - A layer consisting of well decomposed organic matter unrecognizable as to origin. The A_{02} horizon.